# THE CARIES ANALYSIS SYSTEM: A SURFACE-SPECIFIC DESCRIPTION OF CARIES IN THE PRIMARY DENTITION

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## ABSTRACT

Introduction: There is limited information about the caries experience of preschool children. However, the data available suggests caries levels have declined since the introduction of the decayed, missing and filled (dmf) index for recording caries experience. Caries is now concentrated in a small number of individuals, giving rise to high population variance and non-normal caries distribution. The dmf index in such situations may no longer be adequate to detect differences in caries experience between populations, and may result in low mean values, detracting from the seriousness of caries in affected individuals. In addition, the dmfs index does not distinguish between anatomical differences and specific aetiological factors that affect caries rates in individual teeth and surfaces. Preventive agents also have varying levels of efficacy on different tooth surfaces. These findings suggest that a new method of measuring caries in the primary dentition is required. The proposed new method, "The Caries Analysis System" (CAS), will examine surface-specific caries patterns and focus on those children with disease.

Materials and Methods: The CAS was utilized in a cross-sectional study to examine the caries experience of four different preschool populations: 400 Beijing children; 2118 Navajo children; 127 Apache children; and 1218 Arizona children. The CAS identified four caries patterns: maxillary anterior; fissure; posterior proximal; and posterior buccal/lingual smooth. The percentage of affected children (prevalence), the degree to which those children were affected (severity), the proportion of total caries each disease pattern comprised (distribution), and the combination of patterns experienced (pattern combination) were examined to determine whether the prevalence, severity and distribution of caries patterns varied with age or socio-economic status, whether caries patterns predicted future caries, and whether the CAS was more sensitive than the dmf index in determining caries risk.

Results: Caries patterns varied by age. The maxillary anterior pattern developed first, becoming more prevalent until age three. The fissure pattern developed next and rapidly became the most prevalent and severe pattern. It was experienced by nearly all caries positive children. The posterior proximal pattern developed last. Caries pattern distribution varied by age with maxillary anterior caries predominant in the youngest children and fissure and posterior proximal caries predominant in the oldest children.

Caries patterns were associated with caries risk. Among caries positive children, those with maxillary anterior caries had a greater prevalence of the posterior proximal pattern and buccal/lingual pattern and a greater severity of the fissure pattern. Caries patterns also varied by socio-economic risk factors such as household income. Children from high income households experienced a lower prevalence of all patterns, especially the maxillary anterior pattern. However, the severity of the patterns did not differ by income group except for the fissure pattern.

A positive association was found between dmf score and pattern prevalence except for the fissure pattern. When pattern combination was examined, children with high dmf scores had all the patterns. However, at lower dmf scores children had a variety of pattern combinations allowing differences in caries risk to be detected where the dmf index could not.

Conclusions: This study expands existing knowledge of caries in preschool children and suggests that caries patterns as described by the CAS: (1) vary by age; (2) vary according to socio-economic risk factors such as household income; and (3) may distinguish between children of different caries risk where the dmf index cannot. Therefore caries pattern analysis using tools such as the CAS provides more information than the dmf index alone and has potentially beneficial applications in risk assessment, implementation of prevention programs and aetiological studies.

# DECLARATION

This thesis is the sole work of the author with the exception of the help and guidance from the individuals acknowledged in the text.

Joanna M. Douglass

# PREVIOUSLY PUBLISHED MATERIAL

Sections of this thesis are based on the following previously published papers:

Caries prevalence and patterns in preschool Connecticut and Beijing children.
Douglass JM, Wei Yi, Zhang Bo Xue, Tinanoff N.
Community Dentistry and Oral Epidemiology, 1994:22:94-9.

Caries experience in 2003 Native American preschool children.
O'Sullivan DM, Champany R, Tinanoff N, Tetrev S, Douglass JM.
Journal of Public Health Dentistry, 1994:54:139-44.

Caries experience of three- to six-year-old Beijing children.
Douglass JM, Wei Yi, Zhang Bo Xue, Tinanoff N.
Community Dentistry and Oral Epidemiology, 1995:23:340-3.

Temporal changes in caries levels and patterns in a Native American preschool population.
Douglass JM, O'Sullivan DM, Tinanoff N.
Journal of Public Health Dentistry, 1996:56:171-5.

Dental caries prevalence and treatment levels in Arizona preschool children.
Tang J, Altman DS, Robertson D, O'Sullivan DM, Douglass JM, Tinanoff N.
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# CHAPTER I

# THE MEASUREMENT OF DENTAL CARIES IN CHILDREN

## INTRODUCTION

The measurement of dental caries has evolved since the first efforts in the 1920s. However, the changes that have taken place have not necessarily kept pace with our understanding of the disease, or the changes in caries experience of many populations. This review will detail the development of caries indices, the role of individual teeth and surfaces in the analysis of the carious process, the temporal changes in caries experience, and the detection of individuals with high caries risk. Since a large proportion of the literature pertains to the permanent dentition, information related to the permanent dentition will be discussed first.

## THE DEVELOPMENT OF CARIES INDICES

### Permanent Dentition

During the 1920s and the 1930s it became clear that a standardized measure of dental disease was necessary to assess the extent of dental disease within populations, to explore the aetiology of caries, and to evaluate the effectiveness of treatment programs (Morelli, 1924; Bodecker, 1931). Caries prevalence, i.e., the percentage of a population with caries, was one of the first early caries measures (Klein and Palmer, 1937). However, this simple caries measure had little meaning during the 1930s as over 90% of the population experienced caries (Jackson, 1950; Dunning, 1986).

Using the tooth as a unit of caries measurement was first suggested in the 1920's. The number of carious teeth in an individual were compared to the number of non-carious teeth present. Missing teeth were excluded from the analyses (Morelli, 1924; Entin, 1927 in Bodecker, 1931). Such a system did not facilitate comparisons between populations and was inexact for research purposes because the extent to which individual teeth were carious could not be ascertained. For example, a single carious surface that expanded to two surfaces showed no caries increment. A new system was proposed that involved counting the number of carious surfaces. Selected teeth were examined, each of which was allocated four to six caries susceptible surfaces depending on the tooth (Bodecker, 1931).

The Bodecker index was initially criticized as canines and lower incisors were not included (Day and Sedwick, 1935). The index was subsequently modified. All teeth in the dentition were included and all were allocated five susceptible surfaces with a few exceptions. Teeth with distinct oblique ridges were allocated two occlusal surfaces to allow for separate carious lesions in each area and proximal lesions were counted as two surfaces because treatment requires a two surface restoration (Bodecker, 1939). Although the modified index overcame some of the earlier problems and was used in several studies, it never became universally accepted.

Klein and Palmer revised the concept of the tooth as a unit of caries measurement with the introduction of what is now known as the "DMF" index. Since he described dental caries as a cumulative disease, both “past” and “present” disease were included by counting decayed, missing and filled teeth (DMFT) (Klein and Palmer, 1937). The analysis of caries using DMF teeth allowed some of the first detailed studies of total caries experience, treatment rates and the effect of increasing age on total caries experience. In subsequent papers the number of decayed, missing and filled surfaces also were counted (DMFS) (Klein et al., 1938).

A variety of other indices were developed in the hope of more accurately reflecting the extent of individual carious lesions by incorporating the size and depth of the lesions into the computation of the index (Day and Sedwick, 1935; Knowles, 1948; Mellanby and Mellanby, 1948; Stones et al., 1949; Jackson, 1950; Wagg, 1974). These indices scored the size of individual cavities on a scale of one to three or four. The scores were totaled and divided by the number of erupted teeth, or the number of mouths examined or the number of teeth present. Each of these indices, to a lesser or greater degree, reflected not only the extent of individual lesions but also the prevalence of lesions. To date, none of these indices have received much use.

Of the many indices proposed during the 1920s, '30s, and '40s, only two have stood the test of time: caries prevalence as expressed by the percentage of people with caries; and the DMF index. The DMF index has become the "gold standard" to measure lifetime caries, allowing assessment of caries levels, treatment needed and treatment received within populations. However, in individuals over the age of approximately 25 years, loss of teeth through periodontal disease decreases the accuracy of the DMF index as a measure of caries. The index in older individuals reflects overall dental health.

The use of DMFS is more common in modern literature than DMFT, possibly because lower caries levels and longitudinal studies require a sensitive caries measure that reflects caries changes within a single tooth. However, the surface allocation in the DMFS index has not been standardized. Klein implied all teeth have five surfaces as root stumps or crowned teeth received a score of 5 (Klein et al., 1938). Dunning in his textbook of dental public health also implied that all teeth have five surfaces as the maximum number of available surfaces was 160 i.e., 5x32 (Dunning, 1986). In contrast other reports considered that canines and incisors only have four surfaces (Spolsky et al., 1983; Bohannan et al., 1984a). Such apparent inconsistencies, coupled to the fact that many papers have not defined the number of surfaces utilized, has hampered comparison and interpretation of studies.

Differing levels of treatment in study populations also complicates the use of the DMFS index. Dental treatment inflates the index due to the iatrogenic involvement of sound surfaces in the restorative process. For example, a tooth with single surface distal caries requires a two surface distal-occlusal amalgam restoration; a tooth with occlusal caries needing pulp treatment often requires a five surface crown. Such treatment complications are avoided with the DMFT index.

Another characteristic of the DMF index is that it reflects caries prevalence (i.e., the number of people with the disease) and caries severity (i.e., the number of lesions in those with caries) (Spolsky et al., 1983). Therefore two separate populations could have similar average DMF scores even though one population had a high caries prevalence but a low caries severity and the other population had a low caries prevalence but a high caries severity. This drawback was recognized as early as 1937 and in one report caries "severity" was expressed as the number of DMF teeth per 100 mouths attacked by caries (Klein and Palmer, 1937). Severity also is influenced by the number of teeth at risk, something the DMF index does not account for (Striffler et al., 1983). This is a problem in the mixed dentition when the number of teeth present constantly change (Glass et al., 1970). In spite of these drawbacks, the DMF index has remained the most widely accepted and used caries measurement.

## Primary Dentition

Until 1944 the measurement of caries in the primary dentition was neglected. It was felt that "an equivalent measurement of the complete caries experience in the deciduous teeth [was] not possible [as] a definitive decision [could] not be made as to whether a missing deciduous tooth [had] been carious"(Klein et al., 1938). However, caries measurement for the primary dentition was needed and the "deft" or "decayed, extracted and filled tooth" index was developed. The decayed component represented carious teeth that needed restoration, the extracted component represented carious teeth present in the mouth that required extraction (not teeth already extracted) and the filled component represented teeth with restorations present. This was called charting "observable decay". No attempt was made to record teeth that were not present as it was felt that an informed judgment could not be made as to the reason for their loss (Gruebbel, 1944).

A second system for the measurement of caries in primary teeth, more directly based on the methods used in the permanent dentition, was suggested. Decayed, missing and filled teeth or surfaces were counted as in the DMF index. The full primary dentition was only examined in 3-5 year old children when all the primary teeth were erupted and none yet exfoliated. From 5-8 years of age only the primary molars were examined. Beyond the age of 8 years, the index was not used due to exfoliation of the molars. To distinguish this index from the DMF index, lower case "dmf" was used (Jackson, 1950).

Both the deft and dmf indices have been widely used. However, the majority of authors have not used the indices as originally intended. In studies where deft has been used, the "e" component frequently referred to teeth extracted due to caries (Gray, 1967; Slack and Burt, 1981; Holland and Crowley, 1982; Harrison and Davis, 1993). Where dmf has been used, it has not been limited to the age groups originally described. Furthermore, the drawbacks discussed for the DMF index also apply to the deft and dmf indices.

## SIMPLIFIED CARIES INDICES FOR THE PERMANENT DENTITION

Indices based on counting carious teeth or surfaces produced detailed information, but were labor intensive, especially in an era when the majority of the population experienced caries. In an attempt to reduce examination time associations between age specific caries prevalence and the DMFT index, and between the DMFT and DMFS indices were explored. A lack of independence between these different caries measurements was found. It was suggested, therefore, that much time and effort could be avoided by measuring caries prevalence and not DMF scores (Knutson, 1944; Knutson, 1958).

The Knutson method of relating caries prevalence to DMF scores was independently evaluated. The assumptions and equations were found to be correct with certain limitations. The method was most suited for five- to eleven-year-old populations with caries prevalences lower than 75% (Korts et al., 1978).

However, a full mouth examination was still needed to verify whether a subject was caries free. Another proposed system used the caries status of a few select teeth to calculate an estimated DMFT score. The caries status of the lower permanent first molars alone or in combination with the upper centrals in a population were found to be strongly associated with the average DMFT score (Veigas, 1969). Neither of these methods of evaluating caries have been used extensively.

## THE ROLE OF INDIVIDUAL TEETH AND TOOTH SURFACES IN ANALYZING CARIES EXPERIENCE

### Permanent Dentition

Early indices, including the DMF index, did not allow for classification of decay by individual teeth (e.g., molars versus incisors) or different surface types (e.g., fissure versus proximal). However, clinical experience showed that in the permanent dentition different morphological tooth types varied in their tendency to be attacked by caries. Ninety-one percent of DMF surfaces in six-to fifteen-year-olds were accounted for by first molars (Klein et al., 1938). It was also shown that individual surfaces contributed differently to the caries experience of a dentition, with the majority of carious surfaces accounted for by occlusal surfaces (Day and Sedwick, 1935; Klein et al., 1938; Knutson et al., 1940).

In a subsequent study it was found that the caries experience of certain groups of teeth was similar and varied according to post-eruptive age. Lower first and second molars developed caries the soonest after eruption while lower incisors and canines did not develop caries until much later. It was suggested that examination of the epidemiology of caries among specific teeth within a single mouth might contribute significantly to the search for the aetiological factors of caries (Klein and Palmer, 1941).

Grainger and Reid, developing on the idea that groups of teeth experienced decay differently, investigated the decay rates of different surfaces. Anatomical characteristics and changes were found to affect caries rates. The eruption of the second permanent molar was found to increase the decay rate of the distal surface of the first permanent molar and caries of fissure surfaces was found to develop earlier after eruption than caries of posterior proximal surfaces. As a result of these findings it was suggested that an individual's risk of fissure caries was attributable to developmental factors while the risk for posterior proximal caries was attributable to environmental factors (Grainger and Reid, 1954; Reid and Grainger, 1955). This hypothesis was given further support in more recent studies. Children who consumed a higher proportion of their total energy intake as sugars had a greater proximal caries increment but no different fissure caries increment than children who consumed a lower proportion of their energy intake as sugars (Burt et al., 1988). In another study that examined the benefits of a school-based plaque removal program, children who received supervised flossing and tooth brushing had lower rates of proximal caries than the control group but the rate of fissure caries was unaffected (Horowitz et al., 1980).

The ideas that specific surfaces contributed differently to overall caries scores and experienced decay at different rates and times were used in the development of another dental index intended to simplify the caries examination process. The so-called "Grainger Index" divided the dentition into five hierarchical zones. Zone 5 was proximal surfaces on mandibular incisors, zone 4 was labial surfaces on mandibular or maxillary incisors, zone 3 was proximal surfaces on maxillary incisors, zone 2 was posterior proximal surfaces, zone 1 was pit and fissure surfaces and zone 0 was designated as caries free. The examination started by examining zone 5 and proceeded in decreasing numerical order through the zones until caries was detected. Zone 5 represented the worst level of caries and zone 1 the most minimal and common form of caries. The index was criticized after the discovery that some of the zones were not truly hierarchical (Poulsen and Horowitz, 1974; Katz and Meskin, 1976). Modifications were made to the index and it was suggested that "more information exists in knowing where decay was diagnosed in the subject's dentition than in knowing the exact number of surfaces which have been affected" (Kingman, 1978).

Primary Dentition

Similar to the permanent dentition, individual teeth and surfaces in the primary dentition have been shown to vary in their susceptibility to caries. However, little research has been carried out on the primary dentition (Hennon et al., 1969; Glass et al., 1970; Li et al., 1993). Studies have shown the second primary molar to be most commonly affected by caries (Knowles, 1948; Toth and Szabo, 1959; Hennon et al., 1969; Glass et al., 1970; Trubman et al., 1989). Among tooth surfaces the occlusal surfaces accounted for the majority of children's caries experience, with that of the second primary molar most often affected (Knowles, 1948; Parfitt, 1955; Parfitt, 1956; Hennon et al., 1969; Carmichael et al., 1980; Bimstein et al., 1981; Holland and Crowley, 1982; Koch, 1982; Li et al., 1993). The next most commonly involved surface varied according to age. In younger children the mesial surface of the maxillary centrals was most commonly affected, while in older children it was the distal surface of the first molars (Knowles, 1948; Parfitt, 1955; Hennon et al., 1969; Holm, 1975; Bimstein et al., 1981 )

It has been suggested that, similar to findings in the permanent dentition, caries on fissure and proximal surfaces may be under the influence of different risk factors. Anatomical differences between these two surfaces have been reported to result in different patterns of food stagnation, acid production and subsequent caries development (Parfitt, 1955; Parfitt, 1956). The width of interdental spaces, the presence or absence of a contacting distal tooth, the type of tooth (Parfitt, 1956), and the presence of caries on a contacting proximal surface (Bimstein et al., 1981) have been shown to affect the rate of proximal caries, while fissure caries has been suggested to relate to the area and depth of the grooves (Parfitt, 1955). Furthermore, no relationship was found between the number of proximal carious lesions and the number of fissure lesions (Parfitt 1956). However, another study found that teeth with fissure caries were more likely to have proximal caries than those without (Bimstein et al., 1981).

Adding weight to the argument that caries on fissure and proximal surfaces may be under the influence of different risk factors, it was found that the distribution of caries changed with age from two to seven years. The proportion of occlusal caries declined while that of posterior proximal caries increased (Parfitt 1956, Holm, 1975; Varpio, 1981).

It also has been observed that the prevalence of caries on different surfaces depended on the age of the child when caries first developed. Children who didn't develop caries until 5 years of age or later had fewer occlusal surfaces affected than those who developed caries at age three. However, the children in the late caries group had nearly the same number of proximal surfaces carious as the early caries group (Varpio, 1981).

Caries in the primary dentition, like the permanent dentition, differs by tooth and surface type, by the presence or absence of adjacent teeth or caries, and by age. However, unlike in the permanent dentition, sites of dental caries have been suggested to relate more directly to different aetiologies (Rule, 1982; Johnsen et al., 1984). The most classic example of surface-specific caries with a definable aetiology is nursing caries, also called baby bottle tooth decay and more recently early childhood caries. It is thought that children who sleep with a bottle containing milk or juice are more likely to develop caries of the maxillary incisors (Ripa, 1988).

Johnsen designed a caries index specific for the primary dentition based on grouping together surfaces that had identifiable caries aetiologies and distinctive anatomy. The patterns chosen were, in ascending order of severity: caries free; pit and fissure caries; caries associated with hypoplastic lesions; facial-lingual smooth surface caries; proximal molar lesions; and facial-lingual plus molar proximal. Children were placed in only one category, with priority given to smooth surface lesions. The prevalence of caries patterns changed with age. The facial-lingual smooth surface pattern (nursing caries pattern) was the most prevalent pattern up to the age of three years while in five-year-olds patterns with molar proximal lesions were most prevalent (Johnsen et al., 1986; Greenwell et al., 1990). This method of examining caries has been used in several studies to investigate the effect of behavioural and sociological variables on caries experience (Johnsen et al., 1984; Johnsen et al., 1986).

The original caries patterns used in Johnsen's studies were determined from clinical, aetiological and developmental factors. Johnsen has since used a statistical approach to validate the choice of patterns (Johnsen et al., 1993). The cluster analysis used reinforced the notion that caries occurred in distinct patterns. The majority of the children fell into clusters and the clusters were nearly homogeneous for the chosen caries patterns.

## TEMPORAL CHANGES IN CARIES EXPERIENCE

### Permanent Dentition

The first method for preventing tooth decay became available with the discovery of the beneficial effects of fluoride in the 1940s (Stamm, 1984). Since then both the prevalence of caries and the mean number of decayed, missing and filled teeth/surfaces have decreased in most developed countries (Brunelle and Carlos, 1982; Koch, 1982; Stamm, 1984). This decline in caries has been commonly attributed to the use of fluoride in its many delivery systems, including water fluoridation, fluoride dentifrices, and self-applied fluorides (Brunelle and Carlos, 1982), although some authors have felt this may not be the entire explanation (Winter, 1990).

Given that caries on individual teeth and surfaces appeared to be affected by several different factors, it was possible that the caries decline was not uniform across all surfaces. In fact, as early as 1939, Dean found that children living in fluoridated areas appeared to have an "unusually low amount of maxillary anterior caries" compared with children in non-fluoridated areas (Dean et al., 1939). It has since been shown that fluoride preferentially reduces caries in smooth surfaces over fissure surfaces (Rugg-Gunn et al., 1973; Bohannan, 1983; Naylor and Murray 1983; Ripa et al., 1985). As the level of caries declined, the greatest percentage reduction in caries occurred in smooth surfaces. However, the greatest numerical change occurred in fissure surfaces (Kwant et al., 1973; Bohannan et al., 1984; Ripa et al., 1985; Eklund and Ismail, 1986; Li et al., 1993). This finding was due to the greater prevalence of fissure caries compared with smooth surface caries. Even in national surveys not accounting for fluoride status, the greatest percentage reduction in caries occurred on posterior proximal surfaces (Graves and Stamm, 1985; Li et al., 1993). Such a widespread decline in posterior proximal caries may have been because fluoride had become so pervasive that its effects were seen even in children not from fluoridated communities.

Primary Dentition

The change in caries experience of the primary dentition over time has not been as well documented as that in the permanent dentition. However, the available evidence has suggested that caries levels have markedly declined in many developed countries (Graves and Stamm, 1985; Holm, 1990). In some countries this decline may have leveled off (Winter, 1990). The decrease in caries has not been uniform, and there has been a polarization of caries to a minority of the population whose caries rates have remained high (Koch, 1982; Winter, 1990; Quirk Margolis et al., 1994). This polarization of caries has not been apparent in studies where only average dmf scores have been examined rather than dmf frequency tables or the percentage of caries free individuals.

The general use of the dmf index in assessing caries levels has limited the information available on the change in caries by surface. However, similar to the permanent dentition, the greatest percentage decreases occurred in smooth surface caries and the greatest numerical decreases occurred in fissure caries (Carmichael et al., 1980; Johnsen et al., 1986). Among United States children, such changes in caries experiences are not as marked as in the permanent dentition (Li et al., 1993).

In contrast to developed countries, caries levels in the primary dentition of children in developing countries have increased, especially in areas where sugar intake has expanded (Holm, 1990). However, surface-specific information on caries in developing countries has been unavailable with the exception of some studies examining the prevalence of nursing caries (Milnes, 1996).

The decline of caries in developed countries and the increasing number of children that are caries free has led to attempts to detect those children who still develop caries. Identification of such individuals would allow targeting of prevention and treatment programs. The relationship of a variety of variables to caries experience have been investigated, including: demographic factors such as socio-economic status (SES), geographic location and racial/ethnic background; behavioural factors such as diet and oral hygiene; previous caries; and streptococcus mutans levels.

Low SES and parental education levels have both been consistently associated with increased caries experience in the primary dentition as measured by the dmfs/t index (Colquhoun, 1977; Zadik, 1978; Johnsen et al., 1980; Hausen et al., 1982; Carmichael et al., 1989). The association of racial/ethnic background and geographic location with caries experience has not been as clear as for SES, probably because these variables are inextricably associated with SES. The majority of studies that have examined the association of race/ethnicity with caries have examined Caucasian and Black subjects with conflicting results (Infante and Russell, 1974; Heifetz et al., 1976; Weddel and Klein, 1981; Graves et al., 1983). Although Hispanics are the second largest minority within the United States (U.S. Bureau of the Census, 1992), few studies have compared caries levels in Hispanics with Caucasians or Blacks. One study found Hispanic children had greater levels of caries than Caucasians or Blacks (Louie et al., 1990). Among the fastest growing minority groups in the United States are Native Americans (U.S. Bureau of the Census, 1992). Their caries levels have been consistently greater than those of other groups (Harrison and Davis, 1993). The association of geographic location, such as urban versus rural locations, with caries have not been well defined (Cleaton-Jones et al., 1978; Ibrahim et al., 1986; Johnsen et al., 1987).

The relationship between behavioural factors and caries has been difficult to determine, and few studies have been carried out in the primary dentition. Oral hygiene practices have not been correlated with dmf scores or caries prevalence in some studies (Samuleson et al., 1971; Johnsen et al., 1980) while in others they have (Sutcliffe, 1977; Kleemolar-Kujala and Rasanen, 1982). Dietary habits such as high consumption of sweets also have (Holm et al., 1975; Hinds and Gregory, 1995), and have not (Johnsen et al., 1980), been correlated with caries experience.

Previous caries experience in the primary dentition has been weakly correlated with future caries experience in the permanent dentition (Poulsen and Holm, 1980; Klein et al., 1981; Gray et al., 1990). Such an indicator of caries risk has been somewhat unsatisfactory as the subject already has the disease that is to be prevented or treated. The presence of the primary aetiological micro-organism, streptococcus mutans, has been suggested to be a more satisfactory indicator of caries risk. A correlation between streptococcus mutans and caries experience, as measured by the dmf index, has been shown for the primary dentition in several studies (Alaluusua et al., 1989; Holbrook et al., 1989). However, some studies have found the correlation to be weak (Granath et al., 1993).

The lack of consistent associations between risk factors and caries may have been due to an inability to separate out confounding factors, and/or the use of insufficiently sensitive methods of measuring caries. In the aforementioned studies, either the dmfs/t index or caries prevalence was used for measuring caries. However, caries of different surface types may have different characteristics and susceptibilities suggesting that certain risk factors may be more closely associated with surface-specific caries.

Knowles demonstrated that the relative involvement of different tooth surfaces varied between day and residential nursery children. The day nursery children experienced more maxillary anterior caries (Knowles, 1948). In more recent studies, it has been shown that children of low SES appear to be more predisposed to smooth surfaces caries than children of high SES (Carmichael et al., 1980; Johnsen et al., 1987). Furthermore, Johnsen noted that caries free children and those with fissure caries had similar lifestyle characteristics, unlike children who also exhibited smooth surface caries (Johnsen et al., 1984). Children of different racial/ethnic background have also been shown to have different distributions of decay between fissure, buccal/lingual and proximal surfaces (Louie et al., 1990).

Some studies have suggested that behavioural variables could be correlated with surface-specific caries experience. Primary dentition oral hygiene in one study was found to be significantly correlated with caries on proximal surfaces (Holm et al., 1975) and in another was found to be most strongly correlated with caries on maxillary anterior surfaces (Sutcliffe, 1977). One dietary variable, the inappropriate use of baby bottles, has been consistently linked to rampant caries of the primary maxillary anterior teeth (Ripa, 1988). This pattern has been found to be common in particular racial/ethnic groups, notably Native Americans (Bruerd et al., 1989). Infection with streptococci mutans has been strongly associated with the development of this surface-specific disease (Carlsson et al., 1975; van Houte et al., 1982; Milnes and Bowden, 1985).

It has been suggested that surface-specific analyses may be useful in predicting future caries risk. The presence of maxillary anterior caries (nursing caries) has been shown to place children at greater risk of future decay in the primary dentition (Sclavos et al., 1988), particularly posterior proximal decay (Johnsen et al., 1986). It has also been reported that the presence of maxillary anterior caries in the primary dentition is related to high caries rates in the permanent dentition (Kaste et al., 1992). Greenwell et al., in a study evaluating several caries patterns, found that children with fissure caries were twice as likely to have fissure caries of the permanent dentition than caries free children. Those with smooth surface caries in the primary dentition had the greatest risk of caries in the permanent dentition and were particularly prone to smooth surface caries (Greenwell et al., 1990).

## CONCLUSIONS

The traditional decayed, missing and filled index was first developed for use in the permanent dentition and was subsequently modified for use in the primary dentition. This index, which originated in an era when practically everyone developed caries, provided a simple and successful method of comparing caries levels between different populations. Caries levels have since declined, resulting in many caries free individuals. Among those with caries a small number of individuals experience the majority of the disease, which gives rise to high population variance and non-normal caries distribution. The use of the decayed, missing and filled index in such situations results in a low mean value, and thus detracts from the seriousness of caries in affected individuals. Additionally, populations have different caries prevalence (number of individuals with caries) and caries severity (number of carious lesions in those positive for caries), yet the decayed, missing and filled index fails to identify these important distinctions. The use of a single number, as in the decayed, missing and filled index, may no longer be adequate to detect differences in caries experience between populations.

Not all teeth and surfaces are equally predisposed to caries. Anatomical differences, eruption age, the presence or absence of adjacent teeth or carious lesions and the utilization of varying preventive agents affect caries rates in individual teeth and surfaces. Specific aetiological factors are linked to caries of particular tooth surfaces e.g., nursing caries. Preventive agents have varying levels of efficacy on different tooth surfaces e.g., fluoride exhibits the greatest caries reductions on smooth surface lesions. In spite of the importance of these surface-specific characteristics of caries few studies have examined surface-specific caries. The lack of such studies are due, in large part, to dependence on the decayed, missing and filled index which does not distinguish between individual teeth and surfaces. Some studies have used the decayed, missing and filled index and then subdivided the mouth into different surface types, most commonly occlusal, proximal and buccal/lingual. Such a categorization of surface types is not standardized and does not differentiate between smooth buccal/lingual caries and fissure buccal/lingual caries. A standardized system of classifying surfaces based on anatomical, developmental and caries aetiological characteristics is needed to facilitate the investigation of surface-specific caries and aid in the development of surface-specific treatment and prevention programs.

As caries has declined attempts have been made to identify individuals at high caries risk so they may be targeted for prevention and treatment programs. Studies on the primary dentition suggest that demographic factors, behavioural variables, previous caries experience and streptococcus mutans levels affect caries, but in many cases the results are equivocal. Such findings may be due to the insensitive decayed, missing and filled index. A few studies of surface-specific caries do show an association with certain risk factors. The utilization of surface-specific caries measures may therefore allow better identification of high caries risk groups than has been possible using the decayed, missing and filled index.

In summary, caries experience has changed since the advent of the decayed, missing and filled index. For current populations this index alone is insensitive to detect differences in caries experience, assess caries risk, examine aetiological factors or evaluate preventive programs. The lack of standardization and the paucity of information regarding surface-specific caries in the primary dentition suggests that a new method of measuring caries in the primary dentition is required.

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## CHAPTER II

## THE PROPOSED CARIES ANALYSIS SYSTEM FOR THE PRIMARY DENTITION

A new method of measuring cumulative caries experience in the primary dentition is proposed - "The Caries Analysis System" (CAS). This system will focus on only those subjects with caries, thus emphasizing the extent of the disease in affected children. It will differentiate between various caries patterns and examine the percentage of affected children, the degree to which these children are affected, and the proportion of total caries each disease pattern represents. These parameters -- Prevalence, Severity and Distribution, respectively -- uniquely describe caries experience and patterns (Table 2.1). Such parameters have been used previously in the dental literature, though not necessarily with respect to surface-specific patterns.

Table 2.1: Parameter definitions.

| Parameter | Definitions | Example Equation |
|---|---|---|
| Prevalence | % of subjects affected by a caries pattern | $\frac{\text{No. subjects with fissure pattern}}{\text{Total No. subjects}}$ |
| Severity | % of surfaces affected in a specific caries pattern | $\frac{\text{Total No. carious fissure pattern surfaces}}{\text{No. fissure pattern surfaces in subjects with fissure caries}}$ |
| Distribution | % of total caries comprised by a caries pattern | $\frac{\text{Total No. carious fissure pattern surfaces}}{\text{Total No. carious surfaces}}$ |

### THE PARAMETERS

Caries prevalence, although the most simple of caries measures, is sensitive in low caries populations, in the early years after tooth emergence (Dunning, 1986) or when examining populations with wide differences in caries experience (James and Beal, 1981). Hence this parameter in a contemporary primary tooth caries analysis system is appropriate and useful as the level of dental caries has declined, and primary teeth by definition are always examined relatively close to eruption. The information obtained from prevalence measurements will be increased by the use of caries patterns as it has been shown that the prevalence of caries on different types of surfaces varies by age (Parfitt, 1955; Varpio, 1981).

The measurement of caries severity may provide more sensitive information at different ages and in populations with differing caries levels than prevalence information alone (Dunning, 1986). The most commonly used measure of severity, the dmf/DMF index, is most appropriately used in populations with high levels of caries (Spolsky et al., 1983). However, to ascertain whether differences in the extent of disease within individuals exist (especially in lower caries prevalence populations), it is necessary to examine the severity of disease only within affected individuals (Klein and Palmer, 1937). Even then, the dmf/DMF values are not related to the number of teeth at risk (Burt et al., 1992), a consideration of special importance when examining the mixed dentition. The proposed severity parameter for the primary dentition solves both these problems, describing only affected children and accounting for the number of surfaces at risk.

The percentage distribution of carious surfaces among different surface types in the primary dentition has been investigated by several authors (Parfitt, 1955; Holm, 1975). This analysis shows which patterns account for the greatest proportion of caries in a given population. Such a method has been used in the permanent dentition to demonstrate the increasing usefulness of sealants as a method of caries prevention (Bohannan, 1983).

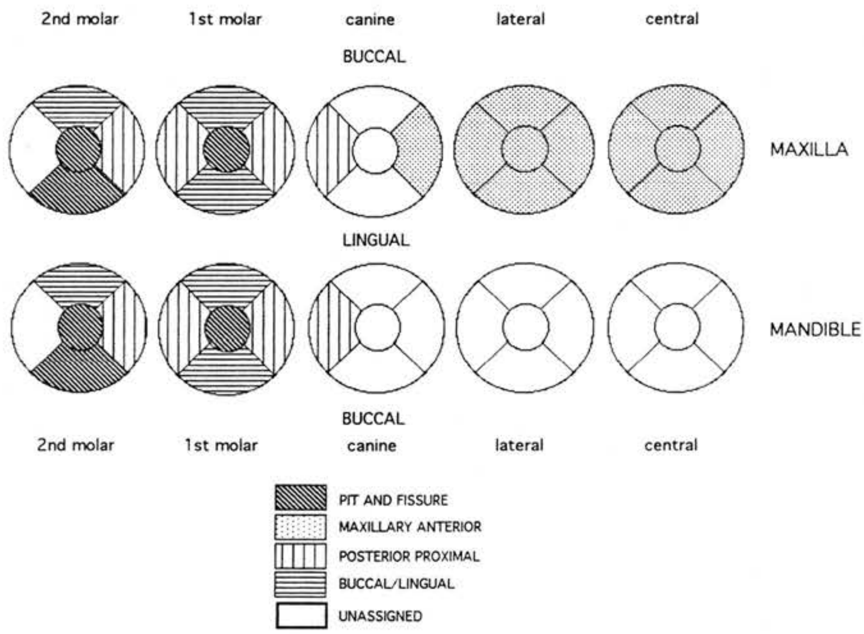
THE CARIES PATTERNS

Caries affecting specific surfaces may have distinct aetiologies (Parfitt, 1956; Johnsen et al., 1984) relating to dietary habits, anatomical and/or developmental factors. Surface-specific analysis of caries has been suggested to have a "special significance for interpreting the severity of the disease" (Rule, 1982) and future caries risk. Furthermore, different caries patterns may require different preventive strategies. The caries patterns in the Caries Analysis System have been chosen to reflect these different factors in primary dentition caries development and prevention.

The "fissure pattern" includes occlusal fissures, buccal pits of mandibular primary second molars and lingual grooves of maxillary primary second molars (Figure 2.1). A similar classification has been used previously in the permanent dentition (Burt et al., 1988). Such surfaces are susceptible to caries due to their anatomy. The deep fissures and pits harbor food and bacterial colonies that remain undisturbed (Parfitt, 1956), allowing cariogenic flora to multiply unimpeded. These areas, that are impossible to clean (Nikiforuk, 1985), are highly susceptible to carious lesions even when exposed to low cariogenic diets (Johnsen, 1984). Although these surfaces also contain smooth surface areas, the vast majority of caries generally is initiated in the pits and grooves. This has been shown to be the case in permanent molars (Sutcliffe, 1974). Caries in this pattern is normally prevented through the use of sealants but can also be affected by fluoride.

The "maxillary anterior" pattern has been suggested to develop when an infant sleeps with the feeding bottle (Figure 2.1). The primary dentition maxillary anterior teeth are thought to be most commonly affected due to their early eruption and the sucking pattern. It is postulated that as the infant sucks, the tongue pushes the milk or juice up around the maxillary teeth while protecting the mandibular incisors (Johnsen, 1984; Ripa, 1988). Although it has been suggested that factors other than the bottle may be important (Reisine and Douglass, 1998). The identification of this pattern is important because of its early onset and because it appears to be a marker of future increased caries risk (Johnsen et al., 1987; Sclavos et al., 1988).

Figure 2.1: Surface composition of proposed primary dentition caries patterns.




The "posterior proximal" pattern, comprising all contacting posterior smooth surfaces, including the distal surfaces of the canines (Figure 2.1), represents primary tooth surfaces where fermentable substrates may remain undisturbed for variable periods of time depending on local factors such as tooth spacing (Parfitt, 1956) and oral hygiene. It has been postulated that caries on these surfaces may depend to a greater extent on conditions in the mouth than caries involving fissure surfaces which is more directly related to the anatomical shape of the surfaces (Reid, 1954; Parfitt 1956). Posterior proximal caries in the primary dentition can be prevented through improved oral hygiene such as flossing (Wright et al., 1979) or toothbrushing (Holm et al., 1975) and also by fluoride which prevents caries of these surfaces better than caries of pit and fissure surfaces (Bohannan, 1983).

The "posterior buccal/lingual smooth" pattern includes all buccal/lingual surfaces of molars without pits and fissures (Figure 2.1), representing surfaces that generally are affected only in extreme disease (Johnsen, 1984; von der Fehr, 1986).

Several surfaces were excluded from the analyses (Figure 2.1). The buccal surfaces of canines were excluded because of the high prevalence of developmental defects in the primary dentition on these surfaces (Silberman et al., 1989; Needleman et al., 1991; Silberman et al, 1991; Duncan et al., 1994). The lingual surfaces of the maxillary canines, the lingual and mesial surfaces of the mandibular canines, as well as the lower incisors were excluded because they are affected only in extreme cases of caries (Johnsen, 1984). The distal surfaces of the primary second molars were excluded as these surfaces change character from free smooth surfaces to contacting posterior proximal surfaces on eruption of the first permanent molar. It is important when excluding surfaces from analysis that they do not contribute significantly to the overall caries experience and that the surfaces remaining in the analysis represent all surface types (Rugg-Gunn, 1975). The proposed system of caries analysis meets these criteria.

The level and type of treatment can affect the prevalence, severity and distribution of caries patterns due to iatrogenic involvement of healthy tooth surfaces during restoration of carious lesions. Hence, the treatment status of carious surfaces in each caries pattern is required to interpret pattern based caries data and determine treatment levels . To achieve this the severity parameter is subdivided into untreated carious lesions, amalgams or composite restorations, stainless steel crowns and extractions. Surfaces that are sealed are considered sound. Surfaces that are not present due to exfoliation or trauma are excluded from the analyses.

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# CHAPTER III

## SPECIFIC AIMS

1. To present a new caries analysis system that allows description of surface-specific caries development in the primary dentition.

2. To examine whether the prevalence, severity and distribution of surface-specific caries patterns vary with age.

3. To show that surface-specific caries patterns may be associated with different caries experience.

4. To examine whether the prevalence, severity and distribution of surface-specific caries patterns vary with socio-economic status.

5. To determine whether surface-specific caries patterns may be more useful than the dmfs index in determining caries risk.

# CHAPTER IV

## THE EFFECT OF AGE ON SURFACE-SPECIFIC CARIES EXPERIENCE

### INTRODUCTION

The aim of this chapter is to determine if surface-specific caries varies by age as described by the caries analysis system (CAS). Additionally the prevalence of caries on individual tooth surfaces will be examined to confirm that the tooth surfaces excluded from the CAS are rarely affected by caries.

Two study populations of preschool children will be used: Chinese children from Beijing in China; and Native American Navajo children from Arizona in the United States. Caries prevalence in preschool Chinese children ranges from 38% in three-year-olds to 91% in six-year-olds and the average number of decayed, missing, and filled teeth (dmft) ranges from 2.0 to 6.4, respectively (Shi et al, 1983; Wright et al, 1989; Wei et al, 1991; Shi et al, 1991; Hu and Liu, 1992), with the majority of the affected surfaces being decayed (Wright et al, 1989; Wei et al, 1991). Such high caries levels are similar to those seen in children from other developing countries (Mosha and Robison, 1989; Holm, 1990) but are markedly higher than those seen in developed countries (Johnsen et al, 1986; Trubman et al 1989; Stephen, 1993). However, not all children in developed countries have low caries levels. There is little information regarding the overall dental health of preschool Native American children but two reports show these children to have a mean dmfs of 9.3 and a mean dmft of 4.9, levels comparable to Chinese children (Kaste et al, 1992; Jones et al, 1992). Interestingly the majority of the literature on Native American preschool caries experience almost exclusively pertains to the prevalence of the surface-specific pattern, nursing caries, which is reportedly as high as 85% (Kelly and Bruerd, 1987; Broderick et al., 1989; Kaste et al., 1992). This pattern has been suggested to be the cause of the high caries levels in these children (Kelly and Bruerd, 1987). No such surface-specific caries information is available for the Chinese children.

The investigation of these two populations with high caries rates and different cultural backgrounds will allow changes in surface-specific caries with age to be examined. Additionally, as the Navajo children are known to receive high levels of dental care through the services of the Indian Health Service, the interaction of treatment choices and caries patterns will also be examined. The information obtained from these populations will add to the understanding of caries levels and development in preschool children with high caries risk, an area of research that has received little attention.

## METHODS AND MATERIALS

### Population 1: Beijing children

A total of 400 three- to six-year-old children, 200 from nursery schools in Beijing, China, and 200 from a farming community close to Beijing, were examined for dental caries over a ten month period in 1990-91. At each location approximately 25 children of each sex and age were examined. Water from the area of the examinations was sampled and found to contain 0.3 ppm fluoride. The available fluoridated toothpaste is mainly manufactured in China and the fluoride levels and bio-availability are generally low.

Dental examinations were performed on-site, using portable dental chairs, mirrors, #23 explorers and focusable flashlights. Each surface was designated as sound, carious, restored or missing. Surfaces were diagnosed carious according to the modified method of Radike (1972) in which fissures were considered carious if an explorer resisted removal after insertion and/or there was loss of normal translucency of enamel next to the fissure. Buccal or lingual surfaces were considered carious if penetrated by an explorer or if enamel could be scraped away by the explorer. Proximal surfaces were considered carious if the marginal ridge showed opacity, or if the explorer recorded discontinuity along with other signs such as opacity or shadow by transillumination. No radiographs were taken. All examinations were performed by the same two examiners (Wei Ye and Zhang Bo Xue) trained in the diagnostic technique. No intra- or inter-examiner calibration was carried out.

### Population 2: Navajo 0-5-year-olds

In 1990 and 1991, 2003 Native American Navajo three- to five-year-old children, were examined for dental caries. All children were participants in the United States federally funded Head Start preschool educational program available to families that are below federal poverty guidelines. More than one hundred centers located in Arizona and New Mexico were included in the study. The majority of these areas are not optimally fluoridated. All children present on the day of examination were included in the study. Clinical examinations were conducted on site using ambient light and dental mirrors, without the aid of dental chairs, by two standardized Indian Health Service dentists. WHO criteria for the diagnosis and recording of caries were applied except explorers were not utilized (WHO, 1987). A surface was considered carious if a break in enamel was detected and/or the enamel was undermined. White or chalky spots, discoloured or rough spots, and stained pits and fissures were not considered carious. Each tooth surface was designated as sound, carious, restored with stainless steel crown, restored with amalgam or composite, or missing due to caries. Radiographs were not used.

A convenience sample of 115 Navajo children less than three years of age also were examined. These children were enrolled in the WIC (Women, Infants and Children) program, a federal supplemental food program for low income pregnant or nursing mothers and children at nutritional risk. While these children were not necessarily representative of the approximately two thousand children enrolled in these Navajo WIC programs, they provided an opportunity to assess caries levels and treatment in an age group that traditionally has been difficult to study because of lack of accessibility. One Indian Health Service dentist performed these examinations under the same conditions and using the same caries diagnostic criteria as for the Navajo Head Start children. Calibration was performed by comparing results of replicate examinations on a subset of the sampled children. Teeth were designated erupted if any part of the tooth could be detected. Surfaces on erupted teeth were designated as sound, carious, restored with stainless steel crown, restored with amalgam or composite, or missing due to caries.

Data analysis

Data entry and analysis for the Beijing population was carried out by Joanna Douglass. Data entry for the Navajo population was carried out by Indian Health Service personnel and subsequent data analysis was carried out by Joanna Douglass and David O'Sullivan. The caries data for the two populations were grouped by age and analyzed using the dmfs/t index and the CAS. To examine the caries prevalence of individual surfaces, the percentage of available tooth surfaces carious among the four-year-old caries positive Beijing children was determined. Statistical differences between dmfs/t, caries prevalence and caries severity by age were analyzed with the Kruskal-Wallis test. The chi-square test was used to analyze differences in distribution by age.

Teeth lost due to trauma were excluded from the analyses as were exfoliated teeth. Exfoliation was only a considerable issue among the six-year-old Beijing children. All lower incisors not present were categorized as exfoliated and caries free due to their very low caries rate. Maxillary incisors not present were categorized as exfoliated and caries free if adjacent incisors had no caries or if all the maxillary incisors were missing. No children younger than six years had had all four maxillary incisors extracted so it was assumed this pattern of non-treatment would not change in the six-year-old children. Maxillary incisors not present that had adjacent carious incisors were considered to have been carious and extracted. This assessment of missing teeth is similar to the methods used in British survey's of children's dental health (O'Brien, 1993).

## RESULTS

### Population 1: Beijing children

The mean dmft and dmfs increased in successive age groups, reaching a maximum of 5.0 and 10.8 respectively in the five-year-olds. Six-year-old children received the most treatment, yet only 16% of this age group's dmfs was comprised of filled surfaces (Table 4.1).

Table 4.1: Caries experience and dental treatment in Beijing children by age.

| Age (yrs) | n | mean dmft* | mean dmfs* | m/dmfs(%) | f/dmfs(%) |
|---|---|---|---|---|---|
| 3 | 95 | 3.45 | 6.84 | 0.0 | 4.8 |
| 4 | 104 | 4.14 | 8.40 | 0.0 | 3.5 |
| 5 | 100 | 4.97 | 11.23 | 1.3 | 9.0 |
| 6 | 101 | 4.59 | 9.61 | 2.4 | 15.7 |

* Significant difference ($p<0.05$) by age.

Analysis of the percentage involvement of the individual tooth surfaces validated the choice of surfaces comprising the caries patterns (Figure 4.1). All surfaces included in the patterns were frequently affected by caries except the mesial surfaces of the maxillary second molar and the proximal surfaces of the canines. Surfaces excluded rarely were affected except for the distal surfaces of the second molars. Among the molar teeth all the mandibular surfaces were affected more than the maxillary. In the fissure pattern the occlusal surfaces of the second molars were affected more than the occlusal surfaces of the first molars. In the maxillary anterior pattern, the central incisors had the highest level of caries, whilst the lowest levels of caries occurred on the mesial surfaces of the canines and the distal surfaces of the lateral incisors. In the posterior proximal pattern the distal surfaces of the first molars most frequently were affected.

Figure 4.1: Percentage of available surfaces carious in 4-year-old caries positive Beijing children.

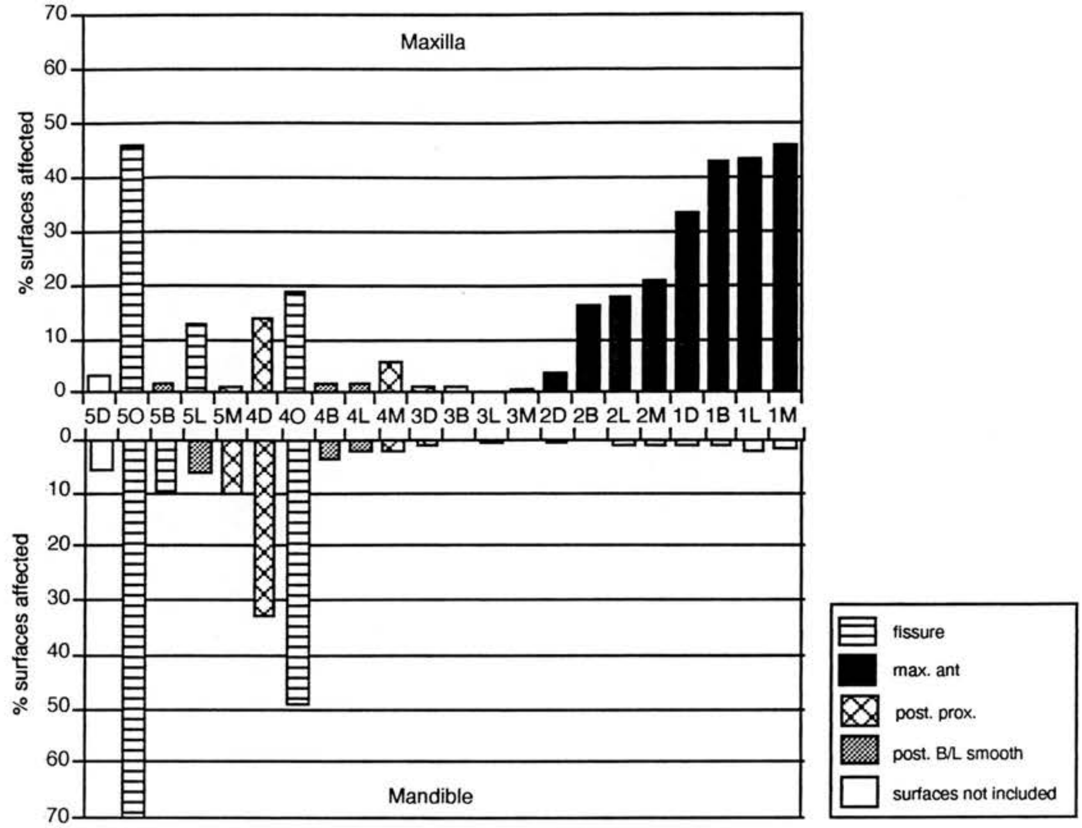
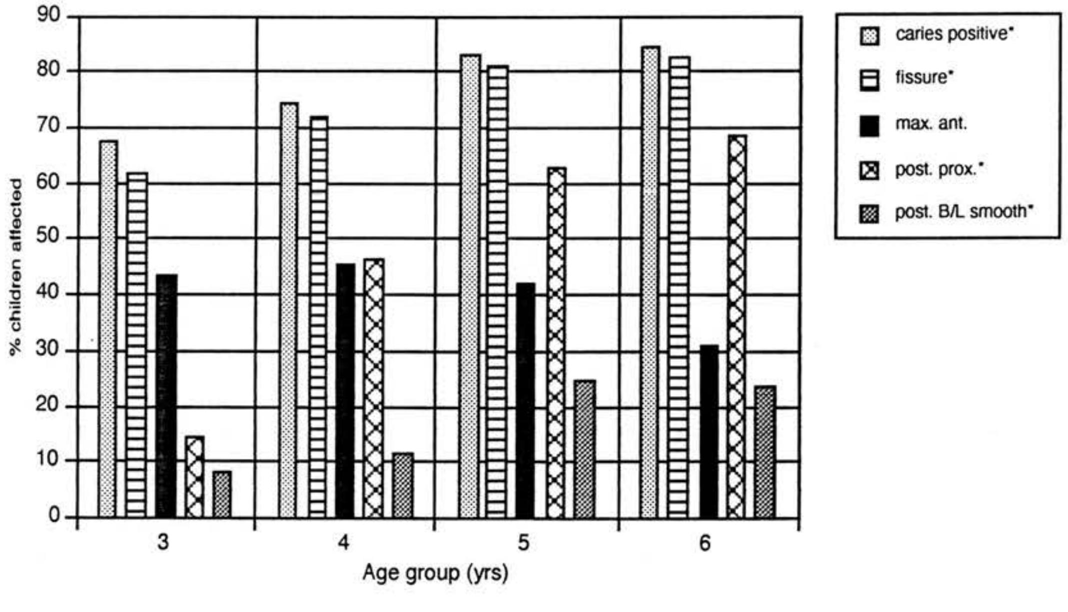


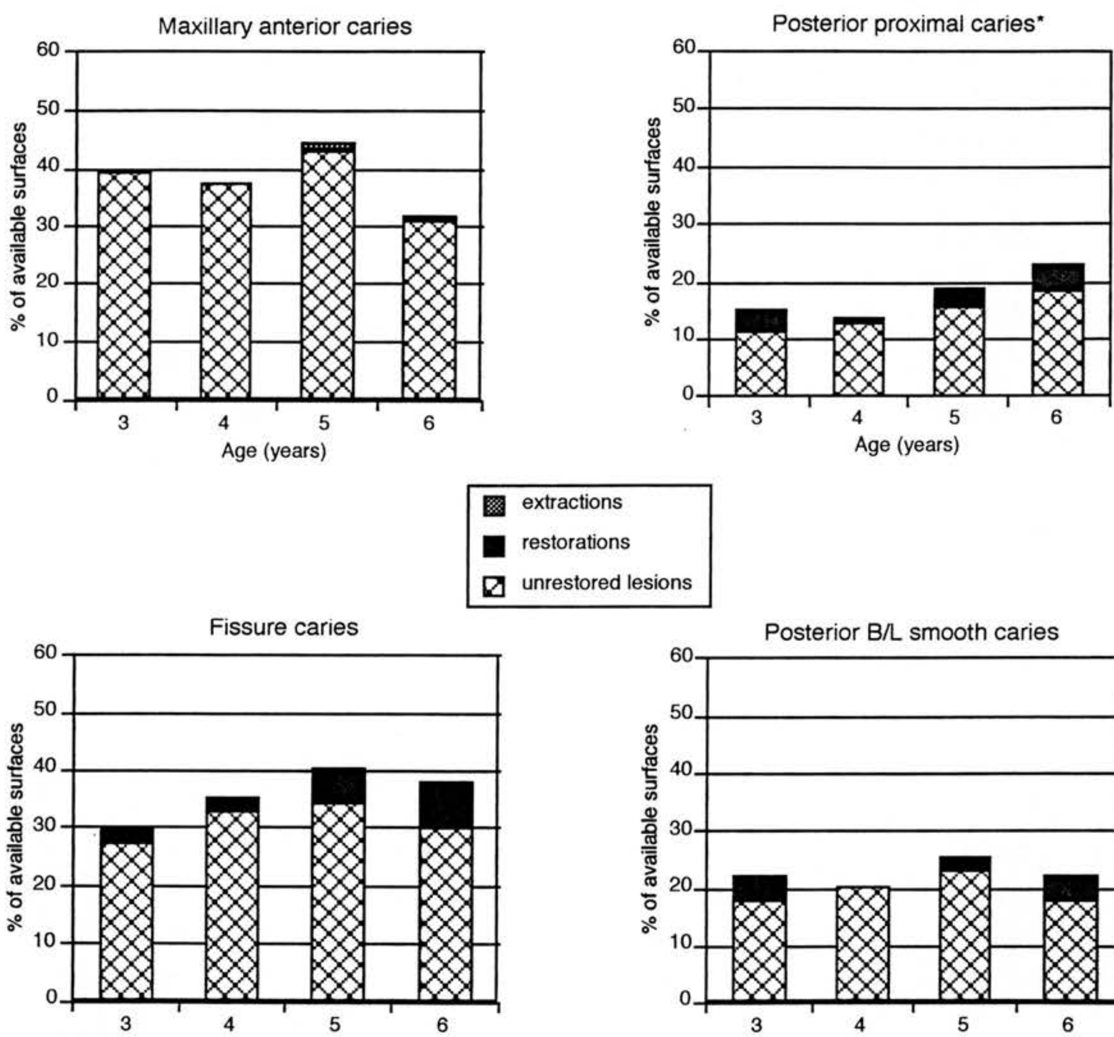

Figure 4.2: Caries prevalence in Beijing children.




*Pattern showed significant difference (P<0.05) by age.

The prevalence, severity and distribution of the caries patterns varied by age. The most prevalent caries patterns in the three-year-old children were the fissure (62%) and maxillary anterior (42%) patterns whilst in the other age groups the fissure and posterior proximal patterns were most prevalent. The maxillary anterior pattern showed no statistically significant change with age; however, the prevalence of the fissure pattern increased in successive age groups reaching a maximum of 82% in the six-year-olds. The prevalence of the posterior proximal pattern showed the greatest change between successive age groups, with a prevalence of 14% in the three-year-olds and 68% in the six-year-olds (Figure 4.2).

Figure 4.3: Caries severity in Beijing children.

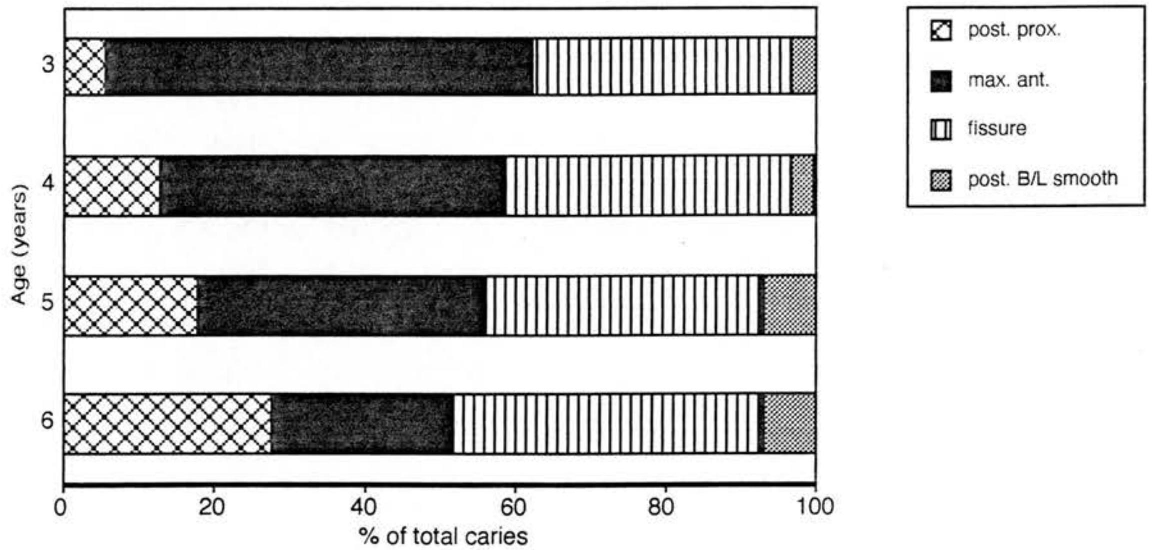



* Pattern showed significant difference (P<0.05) by age.

Maxillary anterior caries was the most severe form of caries with up to 49% of available surfaces carious in children with that pattern. Severity of this pattern changed little with age. The severity of fissure caries was greater in successive age groups, reaching a maximum of 40% of available surfaces affected in the five-year-olds. However, only the posterior proximal pattern, generally the least severe pattern, demonstrated a statistically significant difference in severity due to age. Low levels of treatment were seen in all patterns, especially the maxillary anterior pattern (Figure 4.3).

Distribution of the caries patterns was significantly different between the three- and five-year-olds and the four- and six-year-olds ($p<0.05$). Posterior proximal caries accounted for 6% of the caries in the three-year-olds and 29% in the six-year-olds, whilst the distribution of maxillary anterior caries was 55% in the three-year-olds and 22% in the six-year-olds. The distribution of fissure and posterior buccal/lingual caries changed little with age (Figure 4.4).

Figure 4.4: Caries distribution in Beijing children.




Population 2: Navajo children

The mean dmft and dmfs were greater in successive age groups, reaching a maximum of 6.6 and 18.9 respectively in the five-year-olds. In the five-year-olds 78% of the dmfs was comprised of filled and missing surfaces (Table 4.2)

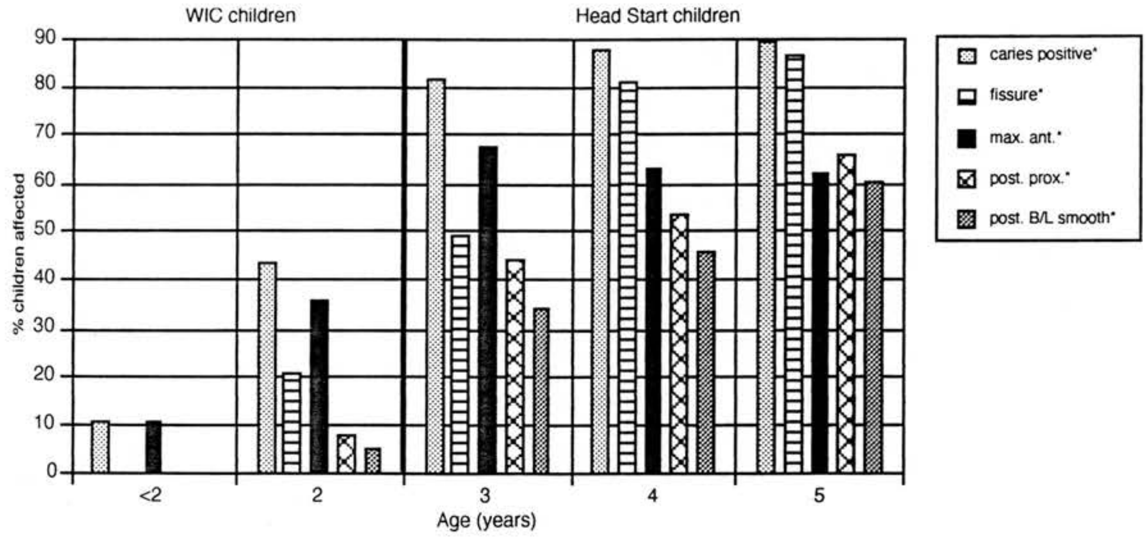
Table 4.2: Caries experience and dental treatment in Navajo children by age and program type.

| Program | Age (yrs) | n | mean dmft* | mean dmfs* | m/dmfs(%) | f/dmfs(%) |
|---|---|---|---|---|---|---|
| WIC | <2 | 76 | 0.24 | 0.45 | 0.0 | 0.0 |
| WIC | 2 | 39 | 1.69 | 3.92 | 16.3 | 13.1 |
| Head Start | 3 | 320 | 4.54 | 10.73 | 14.6 | 48.2 |
| Head Start | 4 | 1385 | 5.95 | 15.29 | 14.6 | 58.5 |
| Head Start | 5 | 298 | 6.62 | 18.94 | 14.4 | 63.2 |

* Significant difference (p<0.05) by age.

The maxillary anterior pattern was the only disease pattern present in WIC children younger than two years, with 11% affected. This pattern was the most prevalent pattern in the younger age groups, with a maximum prevalence of 68% seen in the Head Start three-year-olds. A slight decline in the prevalence of the maxillary anterior pattern was seen among the older age groups, in these groups fissure caries was the most prevalent pattern. Fissure caries, posterior proximal caries and posterior smooth buccal/lingual caries were first evident in two-year-old WIC children and were more prevalent in successive Head Start groups (Figure 4.5).

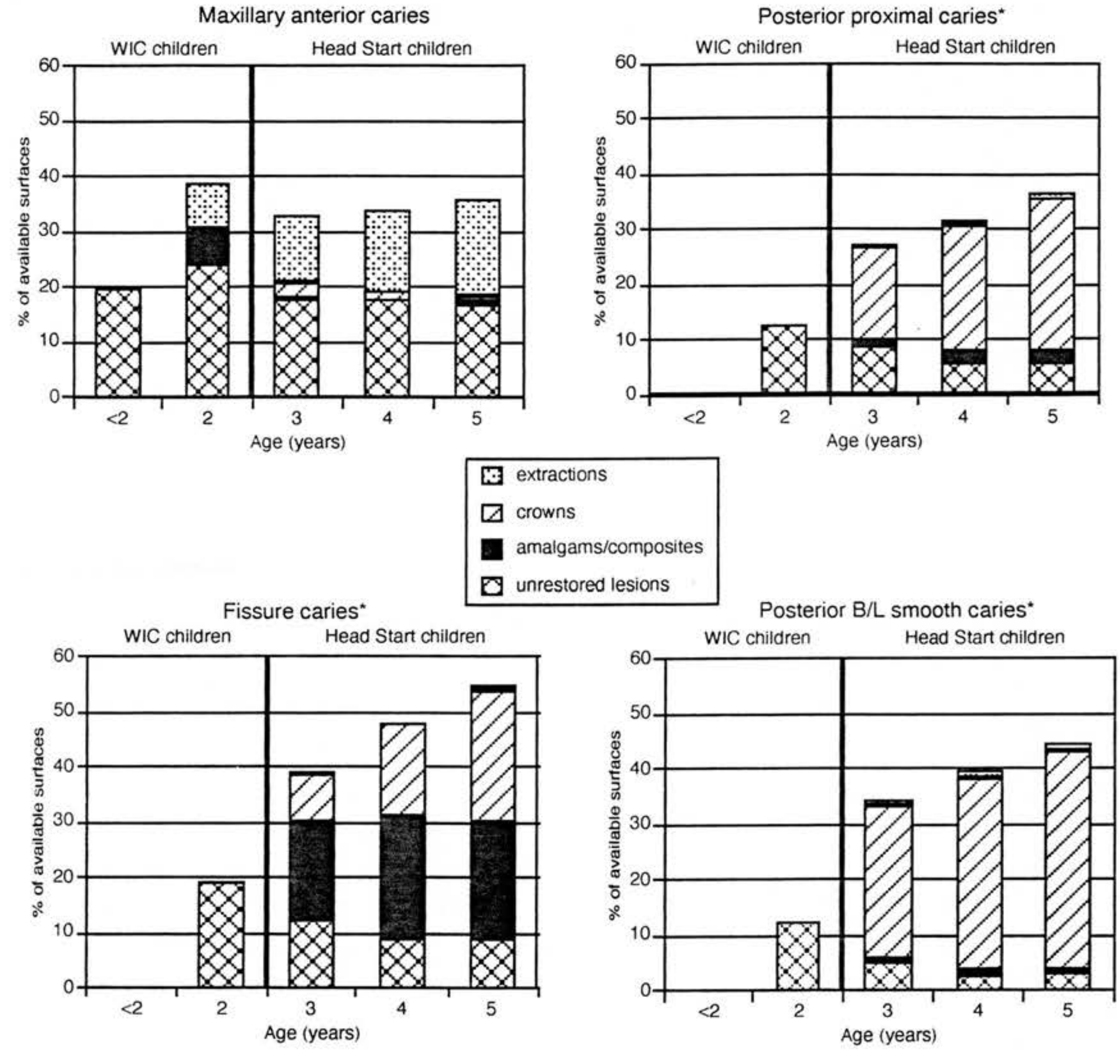
Figure 4.5: Caries prevalence in Navajo children.




*Pattern showed significant difference (P<0.05) by age.

The severity of maxillary anterior caries was 19% in the WIC children younger than two years of age and 39% in the two-year-olds. Among the Head Start children the severity changed little, ranging between 33 and 36%. Treatment was first seen in two-year-olds, with extractions comprising the majority of treated surfaces in all age groups. A larger proportion of the affected surfaces in the maxillary anterior pattern remained untreated compared with the other patterns (Figure 4.6).

Figure 4.6: Caries severity in Navajo children.



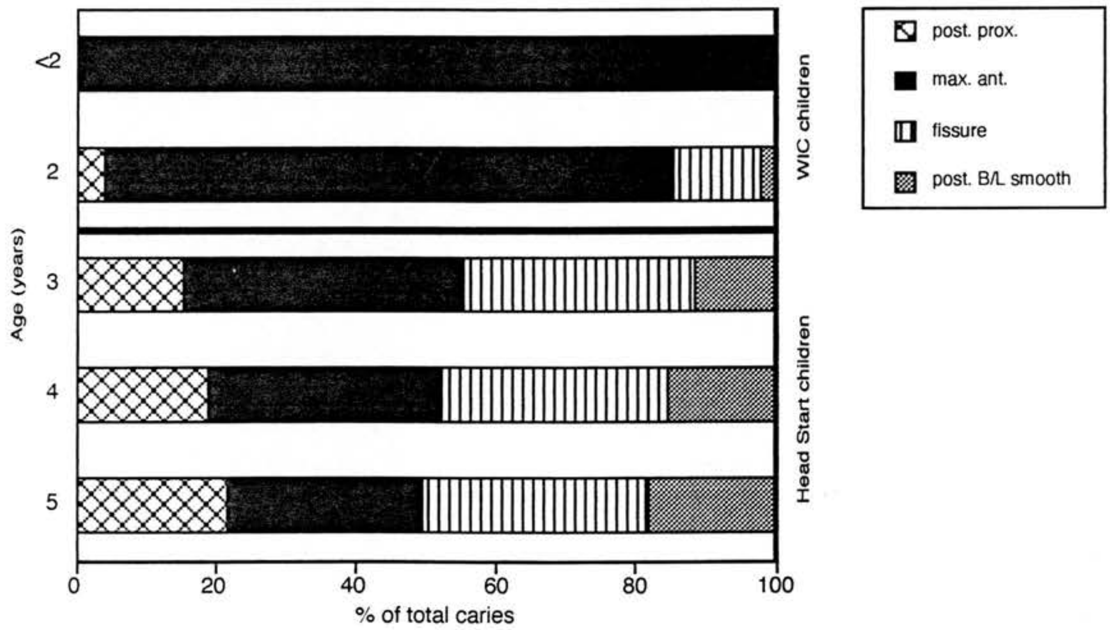

* Pattern showed significant difference (P<0.05) by age.

The severity of fissure caries was greater in successive age groups with 55% of available surfaces being affected in five-year-old children positive for fissure caries. Treatment for this pattern was first seen in the three-year-olds. In this age group treatment was predominantly with amalgam or composite restorations while in the five-year-olds equal use was seen of crowns and amalgams or composite restorations. The severity of untreated lesions was less in successive age groups (Figure 4.6).

The severity of posterior proximal caries also was greater in successive age groups. The vast majority of the treated surfaces were restored with stainless steel crowns (Figure 4.6). The severity of the posterior buccal/lingual pattern was generally greater than that of the posterior proximal pattern while the proportion of untreated surfaces was less than that of all the other patterns (Figure 4.6).

The distribution of the patterns changed with age, though statistically significant differences were only found between the two WIC groups and between the WIC groups and the Head Start groups ($p<0.05$). No difference was found among the Head Start groups. Among the WIC children the maxillary anterior pattern was the predominant pattern. Among the Head Start children the proportion of the maxillary anterior pattern was less in successive groups whilst that of the posterior proximal and posterior buccal/lingual smooth patterns was greater. Little change was seen in the distribution of the fissure pattern (Figure 4.7).

Figure 4.7: Caries distribution in Navajo children.



## DISCUSSION

### Population 1: Beijing children

The dmf scores and the level of dental treatment found in the present population of three- to six-year-old Beijing children are comparable with previous reports from Chinese populations (Shi et al., 1983; Wei et al., 1991; Shi et al., 1991; Wright et al., 1989; Hu and Liu, 1992). However, the level of caries is markedly greater, and treatment notably lower, than that reported for mixed racial/ethnic groups at high caries risk in the United States (Johnsen et al., 1986; Trubman et al., 1989). The general increase of the dmf scores in subsequent age groups reflects the cumulative nature of caries. However, lower scores are found in the six-year-olds which may be explained by either sample error or misclassification of missing teeth.

Only the prevalence of the maxillary anterior pattern declines in older age groups suggesting that misclassification of exfoliated maxillary incisor teeth accounts for the decrease in the dmfs/t score between the five- and six-year-olds. A more aggressive classification of missing teeth as carious and extracted might have better estimated cumulative caries experience. Different classification systems for missing teeth in a population of five-year-olds with similar caries prevalence to the Beijing children varied the dmft score by as much as 1.4 dmft (O'Brien 1993). Changing the classification scheme in the present study, such that all missing maxillary incisors are considered extracted due to caries, changes the six-year-old dmft score from 4.59 to 4.98, the dmfs score from 9.61 to 11.5, the maxillary anterior caries prevalence from 31% to 48% and the severity from 32% to 38%.

The carious involvement of specific tooth surfaces in this population may be explained, in part, by the environment, eruption sequences and anatomical features of the different teeth within each caries pattern. Among the molars, the greater caries levels in the mandibular teeth have been noted in other studies but no reason for such a finding has been suggested (Holm, 1975; Bimstein et al., 1981 ). The large number of occlusal lesions in second molars is expected considering the deeper and more numerous pits and fissures of these teeth compared to first molars (Parfitt, 1955; Finn, 1973 ). However, occlusal surfaces of first molars still are frequently affected, probably because earlier eruption of these teeth compared to second primary molars exposes them to the cariogenic environment for longer. In the maxillary anterior pattern the central incisors, which have the greatest level of caries, erupt first and are exposed to the cariogenic environment the longest. The later eruption of the maxillary canines and the associated primate spaces may explain the low level of caries on the mesial surface of the canines and the distal surface of the laterals (Holm, 1975). In the posterior proximal pattern, the frequently closed contact between the first and second molars along with the thin enamel and other structural/anatomical features of the first molar distal surfaces, may explain the high level of caries on these surfaces (Parfitt, 1956).

The distal surface of the second molar is excluded from the CAS because it changes surface type from free smooth surface to posterior proximal with eruption of the first permanent molar. This has been shown to change its predisposition to caries (Parfitt, 1956). The relatively frequent carious involvement of this surface may be due to occlusal lesions expanding to involve the distal surface. Such events are a problem with surface-specific caries measures in which the clinical examination did not attempt to determine the originating surface of the carious lesions.

Not only can the carious involvement of individual tooth surfaces be explained by environment, eruption sequences and anatomical features, but so can changes in pattern prevalence, severity and distribution. The anatomy of fissure surfaces predisposes them to food and bacteria retention (Parfitt, 1955) explaining why nearly all caries positive children develop the fissure pattern. In fact caries on these surfaces has been suggested to flourish even in the absence of a highly cariogenic diet (Johnsen, 1984). Additionally, in molars, these surfaces are the first to be exposed to the cariogenic diet when they erupt. The early susceptibility to fissure caries is demonstrated by the high severity and prevalence of the disease among three-year-olds. The smaller changes in fissure caries in older children may be because the caries risk of these surfaces decreases with age, similar to that seen in permanent tooth fissures (King et al, 1980). Other studies also report little change in the prevalence of primary tooth fissure caries after the age of five or six years (Parfitt, 1955; Varpio, 1981). Such information suggests there may be only a limited window of opportunity when fissures are susceptible to caries.

In developed countries maxillary anterior caries traditionally has been associated with inappropriate use of the feeding bottle. Infants are put to bed with the bottle containing a sweetened liquid giving rise to rapid carious destruction of the maxillary anterior teeth (Ripa, 1988). This aggressive process may explain the high severity of this caries pattern. However, in China, feeding bottles are not as common as in developed countries. Alternative causes of this caries pattern may include high levels of enamel hypoplasia (Infante and Gillespie,1977; Li et al, 1995), or other cariogenic feeding practices and habits (Reisine and Douglass, 1998), including prolonged/at will breast feeding (Gardener et al, 1977; Matee et al., 1992). The bottle or other cariogenic habit may be discontinued by age three resulting in decreased activity of carious lesions in the maxillary anterior teeth.

The marked change in the prevalence of posterior proximal caries from three- to six-years of age suggests that posterior proximal caries development is later than for fissure caries, probably because contacts must be closed for caries development (Parfitt, 1956; Tinanoff, 1988). However, the lack of radiographs may have resulted in delayed detection of proximal caries. Other studies have reported have reported similar changes in the prevalence of posterior proximal caries with age (Varpio, 1981; Johnsen, 1987). Further, Greenwell et al (1990) and Holt (1975) found posterior proximal caries increment to be greater than that of fissure caries after the age of five years.

The posterior buccal/lingual smooth pattern is the least prevalent. However, it is more severe than the posterior proximal pattern. The posterior buccal/lingual pattern is thought to occur only in cases of rampant decay which may explain the low prevalence but high severity seen in this population (Johnsen, 1984).

Caries pattern distribution is a direct function of prevalence and severity. Although prevalence and severity are used to analyze non-comparable measures (individuals and tooth surfaces, respectively), they both contribute to distribution. As the prevalence and severity of a particular caries pattern increase, the distribution of that pattern increases in proportion to the changes occuring in the other patterns. In these Beijing children, the marked increase in the prevalence and severity of the posterior proximal pattern results in a large change in the distribution of this pattern with age. This finding, combined with the increasing prevalence of the fissure and posterior buccal/lingual patterns and no change in the prevalence and severity of the maxillary anterior pattern with age gives rise to a lower distribution of the maxillary anterior pattern in the older age groups. Similar changes in the distribution of comparable caries patterns have been documented previously (Parfitt, 1956).

Population 2: Navajo children

The current study found a mean dmfs of 18.6 in the five-year-olds, a level of caries that is markedly greater than that of previous studies examining Native American preschool children (Barnes et al., 1992; Jones et al., 1992) and among the highest contemporary dmfs means reported in the world for this age group (Holm, 1990). What distinguishes the children in the present study from the subjects in other reports is the high level of treatment. Approximately 70% of the dmfs in this Head Start population is comprised of treated surfaces. Comparisons with other populations of similar age are difficult because few other populations have received the same high level of dental care. However, the dmft index, in contrast to the dmfs index, may be used to negate treatment effects since number of surfaces affected by the treatment does not alter the dmft number. The extremely high dmft in this Head Start population (mean 6.2 in the 5-year-olds) indicates that even considering the exceptional level of treatment among these children, the level of caries is still remarkable.

The maxillary anterior pattern is the only pattern seen in children less than two years of age, consistent with other reports (Johnsen et al., 1987). The high prevalence of this pattern has been reported in other Native American studies (Broderick et al, 1989; Kelly and Bruerd 1987) but is greater than that reported for other populations (Ripa, 1988). The inappropriate use of feeding bottles also has been suggested to be a cause of this caries pattern in Native American children (Kelly and Bruerd, 1987) which may be exacerbated by the linear hypoplasia found in these children (Infante, 1974). The high prevalence of this pattern may also explain the high caries levels seen in these children since maxillary anterior caries has been reported to place children at risk for future caries (Johnsen et al., 1986).

Although the prevalence of maxillary anterior caries in these Navajo children is high, the severity is similar to that of the Beijing children. Furthermore, the severity in the Navajo children may have been overeported due to the many extractions. It is unlikely that every extracted surface would have been carious. This inverse relationship between prevalence and severity is in contrast to the traditional belief that the greater the prevalence of caries, the greater the severity (Grainger, 1967). In spite of the many extractions carried out for teeth in this pattern, little change occurs in the level of treatment in the different age groups. The priority for treatment of this pattern may be low because of the frequently non-restorable nature of these teeth and the reduced importance of maxillary anterior teeth in dental arch development as compared with posterior teeth.

The prevalence of fissure caries in these Native American children changes with age similar to the Chinese children. However, unlike the Chinese children, the severity of fissure caries among the Native American children shows a marked increase with age while the severity of unrestored lesions actually declines. It is possible that restoration of proximal lesions, resulting in iatrogenic involvment of the fissure surfaces, may in part explain this increase in severity. Further, the absence of explorers may contribute to the lower severity of unrestored lesions in the fissure pattern, however the prevalence was probably unaffected due to the high level of caries and treatment.

The finding that nearly 10% of the two year old WIC children have posterior proximal caries represents perhaps the earliest manifestation of this pattern, which is normally among the latest to develop because it usually requires contacts to be closed for at least one year (Tinanoff, 1988). The prevalence of this pattern changes most markedly between the two- and three-year-olds which is earlier than what was seen in the Chinese children. This may be due to earlier detection of the pattern. Many of the Navajo children received dental treatment and radiographs at age three. This early detection and treatment of lesions results in restorations which are clinically evident during the study examination. Nearly all the treatment seen in posterior proximal pattern is with stainless steel crowns, compared to the fissure pattern where amalgam restorations are frequently used. Stainless steel crowns are more cost effective and last longer than multisurface amalgam restorations (Dawson et al, 1981; Braff, 1975). However, the use of some stainless steel crowns to restore large occlusal lesions can result in iatrogenic involvement of posterior proximal surfaces.

The posterior buccal/lingual smooth pattern is the least prevalent pattern and has the fewest untreated lesions. A high level of posterior buccal/lingual caries might have been expected as this pattern is though to be seen in high caries situations (Johnsen, 1984; von der Fehr, 1986). In fact, nearly all the affected surfaces in this pattern are crowned. This may have protected the surfaces at risk but also suggests that the majority of surfaces in this pattern were iatrogenically involved through the restorative process and that few were actually carious.

The changes in the distribution of patterns are similar to those seen in the Chinese children but are less pronounced. This finding may be due to the high treatment levels in the older age groups resulting in iatrogenic involvement of undiseased tooth surfaces.

Caries patterns and prevention

The information obtained regarding caries patterns can be used to design surface-specific preventive programs for these two populations. Education to alter infant feeding habits could decrease the prevalence and/or severity of the maxillary anterior pattern, hopfully removing risk factors that contribute to later caries development in the posterior teeth. Such methods have been tried among the Native American populations with limited success (Bruerd et al., 1989). A better understanding of the exact dietary factors predisposing to this pattern and the behavioural factors necessary to institute changes in habits may contribute to better results.

The ubiquitousness of fissure caries in both the Beijing and Navajo children suggests that sealants might be an efficacious preventive measure. However, high levels of posterior proximal caries would render sealants redundant as restoration of posterior proximal caries involves the occlusal surfaces. Therefore systemic or topical fluoride may be better preventive measures. Although not as effective in the prevention of occlusal caries, it would be an appropriate preventive choice for the smooth surface patterns. The CAS could be used to analyze the effects of such prevention programs on individual surfaces, allowing programs to be modified as the surface involvment changes.

## Conclusion

The data presented demonstrate that distinct caries patterns can be identified with different ages of onset, prevalence, severity, distribution, treatment modalities and prevention. The maxillary anterior pattern was the most prevalent pattern in the youngest age groups and little change was seen in the prevalence and severity of this pattern in the older age groups. Treatment of this pattern was minimal and mainly limited to extractions. The fissure pattern was found to be the most prevalent pattern except in the youngest age groups. Although the prevalence of this pattern was generally greater in older groups, less change was seen among the oldest age groups. Treatment of this pattern appeared to be mostly single surface restorations in younger children with a possible increased use of crowns in older children. The posterior proximal pattern developed later than the other patterns in the Chinese children but not the Navajo children. The pattern showed the greatest change in prevalence and severity among the older children. Stainless steel crowns appeared to be the treatment of choice for these lesions. The posterior buccal/lingual pattern was the least prevalent pattern, however in the Chinese it was quite severe whilst in the Native Americans it appeared to be almost entirely due to iatrogenic treatment.

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## CHAPTER V

## THE ASSOCIATION OF SURFACE-SPECIFIC CARIES WITH CARIES EXPERIENCE

### INTRODUCTION

The aim of this chapter is to determine if the presence of maxillary anterior caries is associated with greater risk of developing other surface-specific patterns.

Currently, one of the best predictors of future caries is previous caries (Demers et al., 1992; Seppa and Hausen, 1992). The first surface-specific pattern to develop is maxillary anterior caries. This pattern may therefore be a marker for future increased caries risk. A limited number of studies have shown that the presence of maxillary anterior caries may place children at greater risk of future increased caries experience in the posterior primary teeth (Johnsen et al., 1986; Sclavos et al., 1988; Greenwell et al., 1990), especially posterior proximal caries (Johnsen et al., 1986). However, no such studies have been carried out on Native American children. Native American children are known to have among the highest prevalence of maxillary anterior caries with rates reported to be as high as 85% (Table 5.1). This pattern has been suggested to be the cause of the high caries levels found in these children (Kelly and Bruerd, 1987).

Table 5.1: Prevalence of maxillary anterior caries in Native American Head Start children.

| Study | Geographic location | n | Max. Ant. definition | Max. Ant. prevalence |
|---|---|---|---|---|
| Kelly et al., 1987 | Alaska/Oklahoma | 514 | ≥3 Max. Ant. teeth carious | 53% |
| Broderick et al., 1989 | Arizona | 1463 | ≥2 Max. Ant. surf. carious | 72% |
| | Oklahoma | 144 | | 55% |
| Bruerd et al., 1989 | U.S. | 1383 | ≥2 Max. Ant. teeth carious | 58% |
| Barnes et al., 1992 | South-West states | 151 | ≥2 Max. Ant. teeth carious | 35% |
| Kaste et al., 1992 | Arizona | 142 | ≥2 Max. Ant. teeth carious | 76% |

The possible association of maxillary anterior caries with increased risk of developing other surface specific patterns will be investigated in a population of Apache Native American children. The information obtained from this analysis will help to determine the role of maxillary anterior caries in future caries development and the type of preventive programs that might help decrease future caries levels in this highly caries-susceptible population.

## METHODS AND MATERIALS

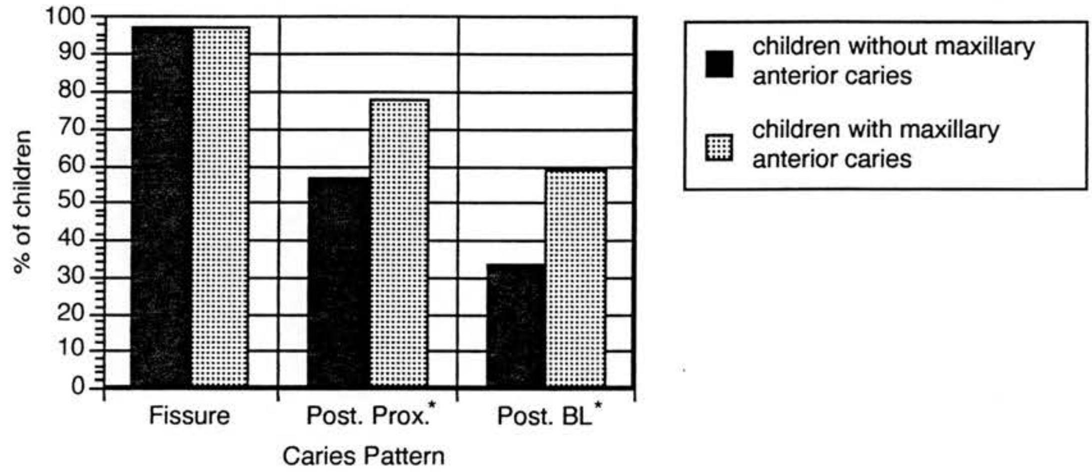
A total of 127 four-year-old Apache children from the Whiteriver (Arizona) Head Start program were examined for dental caries in October, 1993 by two dentists (Joanna Douglass and Norman Tinanoff). These children comprised 94 percent of the four-year-olds enrolled in this Head Start program. Head Start is a federally funded preschool educational program available to families that are below federal poverty guidelines. Dental examinations were conducted using portable dental chairs, mirrors, #23 explorers and focusable flashlights. Caries diagnosis was based on Radike criteria (Radike, 1972) and the results for each child were recorded such that each tooth surface could be indicated as sound, carious, filled (including crowned), or missing due to caries. The examiners reviewed the Radike criteria prior to the examinations and worked in adjacent chairs, allowing questionable diagnoses to be resolved by discussion. Inter-examiner calibration was not conducted due to time constraints. No radiographs were taken.

### Data analysis

All data analysis was carried out by Joanna Douglass using the dmfs/t index and the CAS. The literature examining the prevalence, aetiology and risk factors of maxillary anterior caries has used a variety of clinical definitions for this caries pattern, the most common component of these definitions being two or more carious maxillary teeth (Table 5.1). Therefore, for the purpose of this chapter, children were considered to be positive for maxillary anterior caries if they had two or more maxillary anterior teeth carious. This allowed comparisons with previous literature and a more even split of subjects between those with and without maxillary anterior caries. To determine the impact of maxillary anterior caries on the dental health of these children, the prevalence, severity and distribution of posterior caries patterns among caries-positive children were compared between those with and without maxillary anterior caries. Statistical differences in caries prevalence, severity and distribution between children with and without maxillary anterior caries were analyzed with the Mann-Whitney U test and the chi-square test.

Of the 127 children examined, 95% were caries positive and the mean dmft score was 8.3 and the mean dmfs score was 19.2. Treated surfaces comprised 45% of the dmfs index. Among the caries positive children 64% had the maxillary anterior caries pattern. The prevalence of the fissure pattern was 97% in caries-positive children both with and without the maxillary anterior pattern. In contrast, the prevalence of the posterior proximal and buccal/lingual patterns was nearly 50% and 100% greater, respectively, in children with the maxillary pattern than in those caries-positive children without ($p<0.05$) (Figure 5.1).

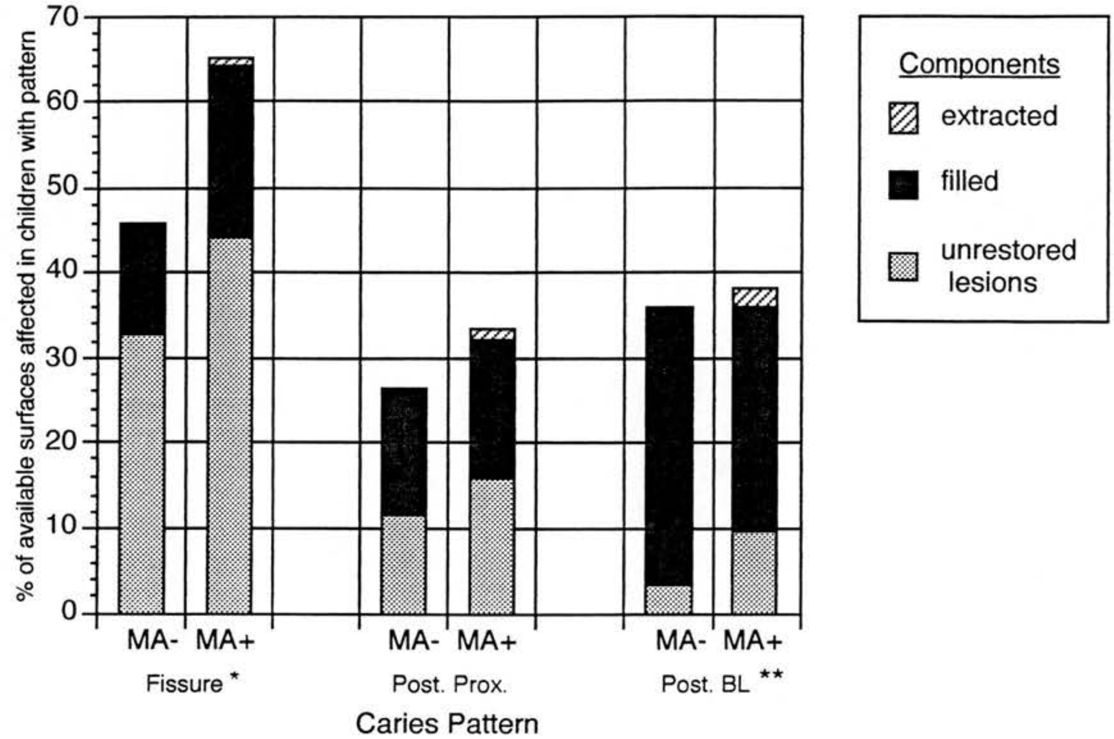
Figure 5.1: The prevalence of posterior caries patterns in caries-positive children with and without maxillary anterior caries




*significant differences between children with and without maxillary anterior caries, $p<0.05$ by $\chi^2$

The severity of the posterior proximal and buccal/lingual patterns showed no significant differences between children with and without the maxillary anterior pattern, but the severity of the fissure pattern was nearly 50% greater in children with the maxillary anterior pattern ($p<0.05$) (Figure 2). There was a significant difference ($p<0.05$) in the distribution of extracted, filled and unrestored lesions between those with and without maxillary anterior caries only in the posterior buccal/lingual pattern. In this pattern children without maxillary anterior caries had a greater percentage of filled surfaces compared to children with the maxillary anterior pattern. The distribution of posterior patterns among children with and without maxillary anterior caries did not differ significantly (Figure 5.3).

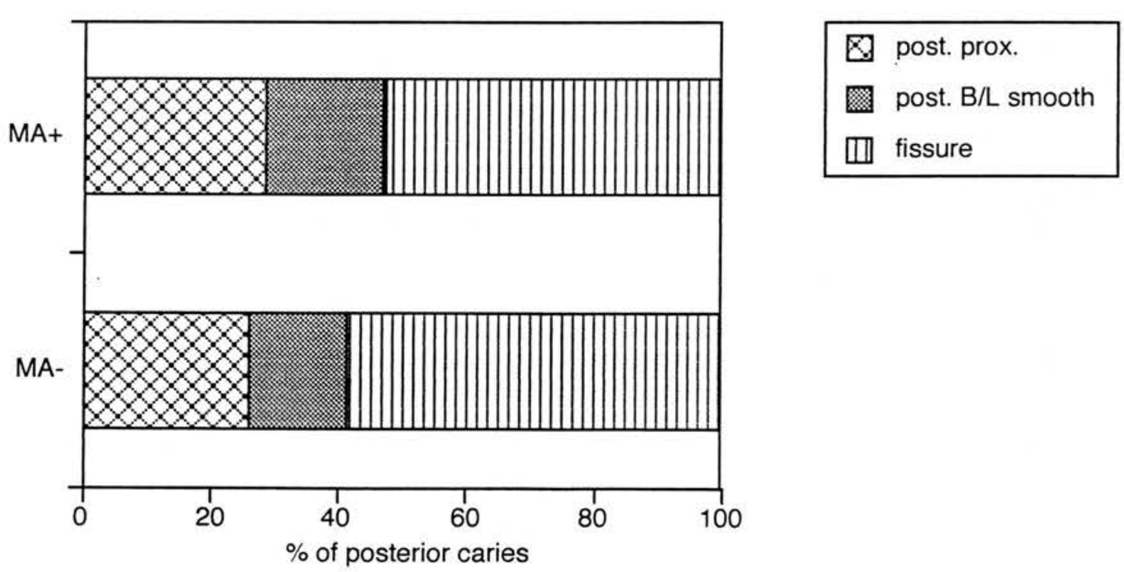
Figure 5.2: Severity of posterior caries patterns in caries-positive children with (MA+) and without (MA-) maxillary anterior caries.




*significant difference in overall severity of caries patterns between children with and without nursing caries, p<0.01 by Mann Whitney U.

**significant difference in distribution of components between children with and without nursing caries, p<0.05 by $\chi^2$.

Figure 5.3: Distribution of posterior caries patterns in children with (MA+) and without (MA-) maxillary anterior caries.



The current study found a mean dmfs score of 19.2, similar to that reported in the previous chapter for the Navajo children. However, treatment levels were much lower. This may be because the children in the current study were examined at the start of the Head Start school year, before much of the treatment provided by the Indian Health Service was initiated.

The high prevalence of the maxillary anterior pattern in this population is consistent with other reports about Native American children (Table 5.1) and represents a significant health problem for these children. The exact etiology of this early pattern is elusive. Traditionally linked to inappropriate bottle use, this etiology is now being brought into question (Reisine and Douglass, 1998). It appears that multiple dietary factors and health behaviours present during the age of bottle feeding and probably persisting afterwards, may be implicated in the etiology of maxillary anterior caries. This may in part explain why these children appear to be at continued risk for future lesions in the posterior teeth even after the bottle habit has been discontinued.

As the fissure pattern is so ubiquitous, it is not surprising that no difference was found in the prevalence of fissure caries between children with and without the maxillary anterior pattern. However, children with the maxillary anterior pattern had a greater severity of fissure caries. The greater severity may be due to the early initiation of the caries process in children with maxillary anterior caries and/or exposure to high levels of fermentable carbohydrates in the bottle along with other poor dietary practices.

It is apparent that children with maxillary anterior caries have a higher prevalence of the posterior proximal and posterior buccal/lingual patterns than those without maxillary anterior caries, yet there is no difference in the severity of either pattern. The posterior proximal and posterior buccal/lingual patterns generally develop later than the fissure pattern (Gordon, 1985; Tinanoff, 1988; Chapter 4). Therefore, these children may be too young to detect differences in the severity of the posterior proximal and posterior buccal/lingual patterns between those with and without the maxillary anterior pattern. Furthermore, the absence of bitewing radiographs may have prevented the detection of small proximal lesions. Alternatively, in the case of the posterior buccal/lingual pattern, no difference may have been detected in the severity of because children without maxillary anterior caries had higher levels of treatment. The highest incidence of iatrogenically involved tooth surfaces secondary to treatment is seen in posterior buccal/lingual pattern (Chapter 4).

The risk factors that contribute to maxillary anterior caries development may be shared by the posterior teeth as the prevalence and severity of posterior caries patterns are adversely affected in children with maxillary anterior caries. Primary prevention of maxillary anterior caries may therefore help reduce posterior caries. However, prevention programs may prove difficult to implement. Maxillary anterior caries is considered the norm among many Native American communities (Milnes 1996) and hence motivation to initiate prevention is difficult.

Children presenting with maxillary anterior caries may need to receive different prevention programs from caries-positive children without maxillary anterior caries. Although children with the maxillary anterior pattern have a greater severity of fissure caries than those without the maxillary anterior pattern, the greater prevalence of smooth surface caries in these children decreases the effectiveness of sealants. Systemic and topical fluorides, and anti-bacterial agents may be more effective choices for children with maxillary anterior caries.

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## CHAPTER VI

## THE ASSOCIATION OF SURFACE-SPECIFIC CARIES PATTERNS AND HOUSEHOLD INCOME

### INTRODUCTION

Knowledge of the prevalence of dental caries in United States preschool children is limited (Waldman 1990), mainly due to difficulties accessing this age group. Most contemporary United States studies on preschool children have looked at 3-5-year-olds enrolled in Head Start, a Federally funded preschool education program for low-income children and families (Table 6.1). Although comparisons between studies are difficult due to the varying caries indices used, among Head Start children mean caries scores are generally in excess of two surfaces, and are much higher in many samples, especially those including Native American children. In contrast, the third National Health and Nutritional Examination Survey (NHANES III), which used weighted estimates of United States populations, reported a dft score of 0.6 (Kaste et al., 1996). This score is lower than those reported in the Head Start studies even accounting for the variation in indices used, though it must be noted that a younger age group was examined. Such a finding suggests that general population caries levels are lower than those seen in low socio-economic Head Start children. However, only a few studies have examined the association of caries with socio-economic status in preschool children and most are more than a decade old (Wisan et al., 1957; Samuleson et al., 1971; Sutcliffe, 1977; Johnsen et al., 1980; Weddel and Klein, 1981; Johnsen et al., 1984). One recent British study showed that preschool children from lower socio-economic families had twice the level of caries seen in children from higher socio-economic families (Hinds and Gregory, 1995).

The relationship of surface-specific caries patterns to socio-economic status has received less attention. Two studies report that children from low socio-economic backgrounds experience more smooth surface caries than children from high socio-economic backgrounds (Carmichael et al., 1980; Johnsen et al., 1987). In particular, the smooth surface pattern, maxillary anterior caries, has been associated with greater overall caries risk (Chapter 5; Johnsen et al., 1986). In contrast, caries risk factors have not been found to vary between caries free children and those with fissure caries (Johnsen et al., 1984). These findings suggest that caries patterns and the combinations of patterns experienced may have

Table 6.1: Levels of dental caries and untreated decay in U.S. preschool children, 1986-1996.

| Study | Geographic location | Population | Age | n | Caries score * | % d |
|---|---|---|---|---|---|---|
| | | | | | dft | |
| Parker et al. 1986 | Random sites | Head Start | | 276 | 2.44 | 39 |
| | | | | | deft | |
| Johnsen et al. 1986 | Rural & city OH | Head Start | 3.5-5 | 1310 | 2.50 | |
| | | | | | dmft | |
| Trubman et al. 1989 | All sites in MS | Head Start | 3 | 210 | 1.34 | 55 |
| | | | 4 | 1003 | 2.58 | 52 |
| | | | 5 | 950 | 3.53 | 43 |
| | | | | | dfs | |
| Louie et al. 1990 | Random sites in CA, HI and Micronesia | Head Start (Micronesian) | 3-5 | 864 | 11.08 | 92 |
| | | Head Start (White) | 3-5 | 138 | 5.22 | 37 |
| | | Head Start (Black) | 3-5 | 110 | 3.66 | 71 |
| | | Head Start (Hispanic) | 3-5 | 295 | 6.62 | 48 |
| | | | | | dfs | |
| Tinanoff et al. 1991 | All sites in Hartford (city) and New London County, CT | Head Start (total) | 3-5 | 401 | 2.19 | 73 |
| | | Head Start (White) | 3-5 | 73 | 1.58 | 58 |
| | | Head Start (Black) | 3-5 | 229 | 2.54 | 73 |
| | | Head Start (Hispanic) | 3-5 | 94 | 1.88 | 81 |
| | | | | | dmft | |
| Jones et al. 1992 | Random 37% of AK Head Start | Head Start (Nat. Amer.) | 3-5 | 381 | 4.88 | 39 |
| | | Head Start (non-Nat. Amer.) | 3-5 | 163 | 1.65 | 22 |
| | | | | | dfs | |
| Barnes et al. 1992 | Random 5% of sites in southwestern states | Head Start (total) | 3-5 | 825 | 6.35 | |
| | | Head Start (White) | 3-5 | 221 | 6.30 | |
| | | Head Start (Black) | 3-5 | 409 | 5.14 | |
| | | Head Start (Hispanic) | 3-5 | 44 | 5.65 | |
| | | Head Start (Nat. Amer.) | 3-5 | 151 | 11.63 | |
| | | | | | deft | |
| Tsbouchi et al. 1995 | Marysville, WA | WIC (Nat. Amer.) | 1-2 | 77 | 2.09 | |
| | | | | | dft | |
| Kaste et al. 1996 | National (US) | Weighted estimate (total) | 2-4 | 1627 | 0.6 | 82 |
| | | Weighted estimate (White) | 2-4 | 502 | 0.4 | 83 |
| | | Weighted estimate (Black) | 2-4 | 489 | 0.7 | 81 |
| | | Weighted estimate (Mex-Amer.) | 2-4 | 578 | 1.3 | 82 |

*dft = decayed and filled teeth (missing teeth not included)
deft = decayed, extracted (or indicated for extraction) and filled teeth
dmft = decayed, missing due to caries (i.e., extracted) and filled teeth
dfs = decayed and filled surfaces (missing surfaces not included)

a role in describing caries risk and explaining the association of caries experience with socio-economic status.

The aims of this chapter are to: (1) increase knowledge about caries in preschool children from various socioeconomic settings; (2) determine if dmfs scores and the prevalence, severity, and distribution of surface-specific caries patterns in children vary with their socio-economic status as described by household income; (3) explore the relationship between the dmfs index and caries patterns; and (4) determine if caries pattern combination may be able to detect differences in caries risk where the dmfs index cannot. These aims will be examined through analysis of the caries experience of 4-year-old Arizona children. The information obtained will associate risk factors with specific caries patterns and help identify children at risk for caries, thereby allowing provision of surface-specific preventive services to children with most need.

## METHODS AND MATERIALS

The study design, acquisition of parental consent, clinical examinations, and initial data entry were carried out by the Arizona Department of Health Services. Dental caries examinations on 5,171 Arizona preschool children were conducted between February, 1994 and September, 1995. The population was recruited from 4 facility types: Head Start programs; Women, Infants, Children (WIC) programs; health fairs; and private day care centers. Head Start and WIC are federally-funded programs whose eligibility requirements include low family income; therefore, these children and their caretakers were considered of low socioeconomic status (SES). Health fairs were annual, community-based events that provided health screenings and education to families of mostly low SES. Since children examined at health fairs also may have been enrolled in Head Start and WIC programs, built-in computer edit checks were used to ensure that no child was counted twice. The private day care centers were chosen because these preschool children and their caretakers were representative of mid-SES families.

Facilities were located in Phoenix, Tucson, and 30 other communities. However, day care centers were located only in Phoenix and Tucson because of difficulty identifying day care centers in smaller communities. Communities were chosen from each of six planning regions designated by the Arizona Department of Economic Security. Within each region communities were classified as small rural (population of 1,000-4,999); large rural (5,000-19,999); small urban (20,000-99,999); and large urban (>100,000). Communities with populations of fewer than 1000 people or fewer than 100 children younger than age 5 were excluded due to the inefficiency of including them. Communities on Native American reservations were also excluded because of prior studies of these communities. From the remaining communities a representative sample of communities in each region was selected by size and geographic location. The aim of the survey was to sample at least 2 percent of the children in each of the 1-, 2-, 3-, and 4-year-old age groups in each community. A minimum sample size of 25 children from the smaller communities was established for each age group (except for less than 1 year). According to statistics from the Arizona Department of Health Services, approximately 70 percent of children younger than age 5 residing in the survey communities had access to public drinking water containing greater than 0.6 ppm fluoride.

Criteria for a child's participation were age and the caretaker's willingness to complete a consent form that gave permission for his/her child to receive a dental examination. The consent form included questions on the child's medical history, family/household income, level of caretaker education, and racial/ethnic classification. Consent forms were printed in English and Spanish, and were completed by the caretakers. Medical conditions did not exclude any child because explorers were not used. Referrals for dental care were made when applicable.

Five calibrated dentists employed by the Arizona State Health Department performed the on-site dental examinations using natural light and dental mirrors. No radiographs were taken. Teeth were coded as unerupted (not yet present in the mouth), or erupted. Tooth surfaces were coded as missing due to caries, missing due to other reasons, decayed, crowned, filled, or sound (without caries and without fillings). Tooth surfaces were considered decayed when a visual break in enamel was observed. Additionally, pit and fissure decay was designated if there was discoloration of a pit or fissure with adjacent opacity; posterior proximal decay was designated when there was visual evidence of undermining of the marginal ridge; anterior proximal decay was designated when transillumination with a dental mirror showed shadowing or loss of translucency of tooth structure.

Calibrations were conducted with children of different ages, following written instructions and discussion sessions. Inter-examiner reliability, using the tooth surface as the level of agreement, was at least kappa = 0.97 between all pairs of examiners. Two of the five dentists conducted 71 percent of the examinations. All data were entered by one individual from the Arizona State Health Department, and built-in edit checks assured acceptable parameters and no duplication of subjects.

Data Analysis

All data analysis was carried out by Joanna Douglass. The 4-year-old children were selected and categorized into two groups according to their household income: less than and greater than or equal to $20,000 per annum. Children of caretakers who declined to or failed to answer the question regarding household income were not included in the analyses. The children's caries experience was analyzed by the CAS and the dmfs index. Statistical differences in prevalence, and distribution were evaluated using the chi square test and statistical differences in severity and dmfs scores were evaluated using the Mann Whitney U test.

Each child was then assigned a mutually exclusive pattern combination (Table 6.2). To limit the number of pattern combinations the posterior buccal/lingual smooth pattern was not used. Additionally a few children experienced caries pattern combinations not listed in Table 6.2. These children were classified based on the pattern considered to present the most high caries risk. Those with just posterior proximal caries (13 children) were classified as *pfpp*, those with maxillary anterior and posterior proximal caries (6 children) were classified as *mapfpp*.

Table 6.2: Caries pattern combination.

| Pattern present | Abbreviation |
|---|---|
| Max. Ant. only | *ma* |
| Max. Ant and Fissure | *mapf* |
| Max. Ant., Fissure and Post. Prox. | *mapfpp* |
| Fissure | *pf* |
| Fissure and Post. Prox. | *pfpp* |

The relationship between the dmfs index and caries patterns was explored by categorizing children according to their dmfs score (1-3, 4-6, 7-9, etc. up to >31 dmfs). The pattern prevalence, severity and distribution along with the prevalence of the pattern combinations were calculated for each dmfs grouping.

Finally, to determine if the use of pattern combinations may be able to detect differences in caries risk where the dmfs index cannot, children with low to moderate dmfs scores of 4-8 surfaces were selected. Differences in dmfs score and pattern combination by household income were assessed using the Mann Whitney U test and chi square test respectively.

Caries experience and household income

Of the 5171 children examined for the study, only 1218 met the criteria of being 4-years-old with information regarding household income. Approximately one half of the study population were reported to be Hispanic and one third White. Eighty percent of the study population was categorized as low income. The dmfs score of the low income group was more than twice that of the high income group ($p<0.01$). However, treatment levels were low in both income groups with nearly half of the dmfs score in the low and high income groups comprising decayed surfaces (Table 6.3).

Table 6.3: Distribution of sample and mean dmf scores by household income.

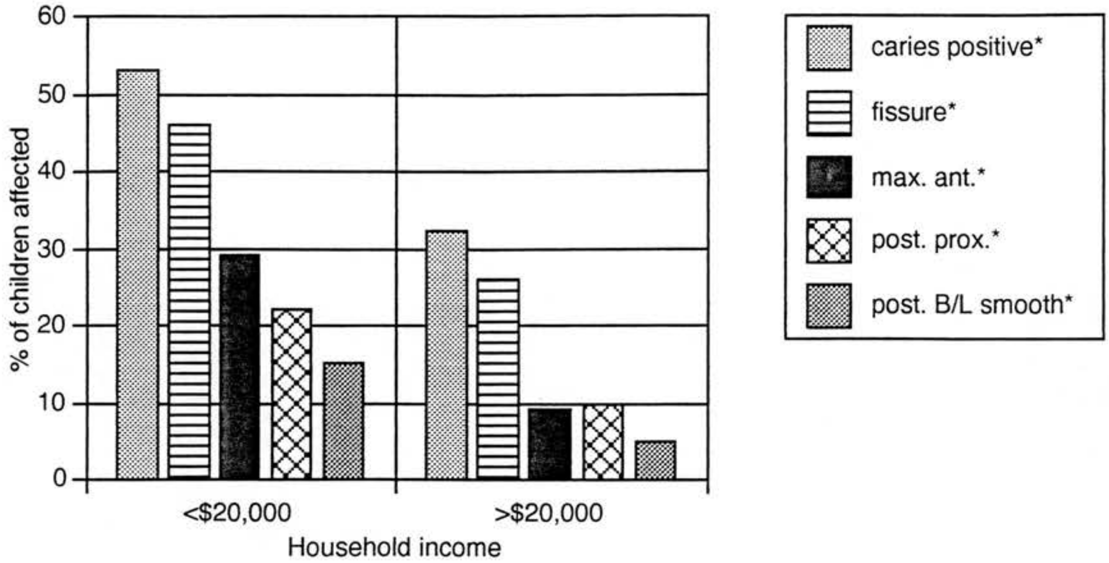
| | <$20,000 | >$20,000 |
|---|---|---|
| % of sample | 80% | 20% |
| n | 975 | 243 |
| dmft* | 2.76 | 1.09 |
| dmfs* | 5.42 | 2.04 |
| ds% | 47% | 42% |

* Caries score showed significant difference ($p<0.01$) by household income

The prevalence of caries and caries patterns was significantly different between the two income groups, with the low income children experiencing a greater prevalence of each pattern ($p<0.01$). Although the low income children experienced caries only one and one-half times more often than the high income children, they experienced maxillary anterior caries nearly three times as frequently and posterior proximal caries more than two times as frequently (Figure 6.1).

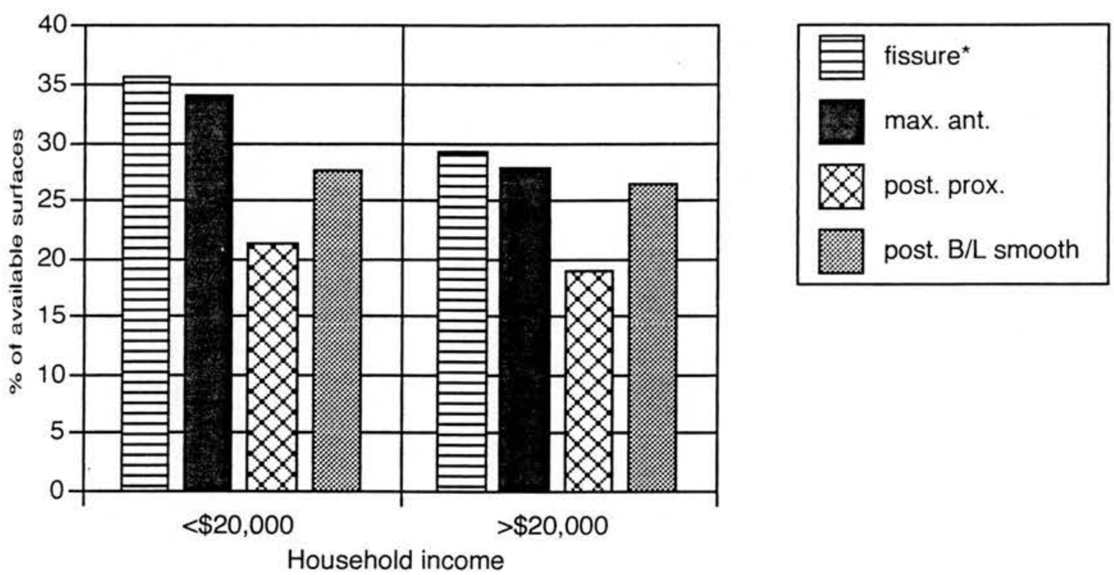
In contrast to pattern prevalence, pattern severity was only significantly different for fissure caries. Thirty-six percent of fissure surfaces were affected in low income children with the pattern compared with 29% of surfaces in high income children. Interestingly, the severity of the maxillary anterior pattern was similar to that of the fissure pattern in the high income group (Figure 6.2).

Figure 6.1: Prevalence of caries and caries patterns in 4-year-old Arizona children by household income.



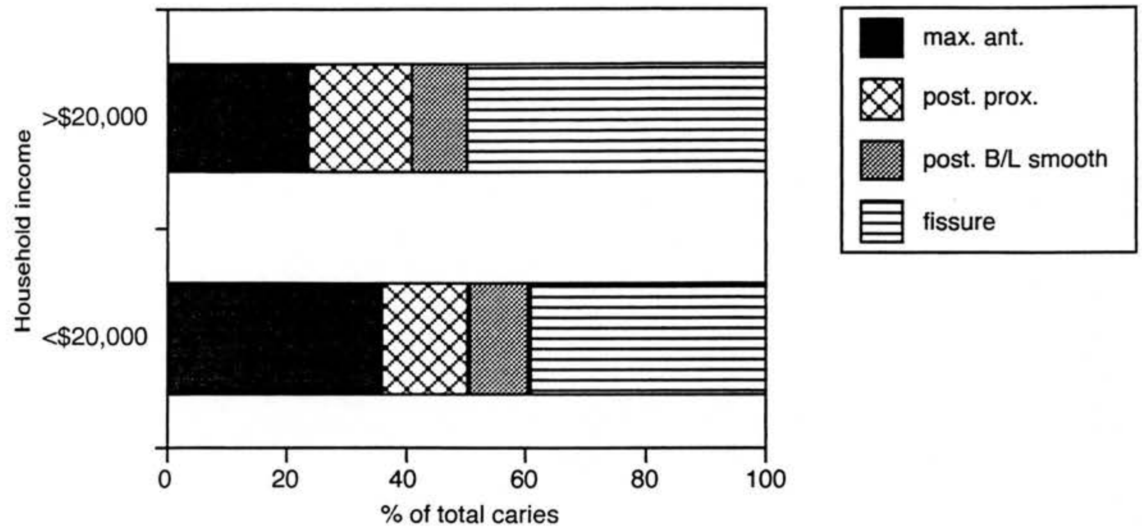

*Pattern showed significant difference (p<0.01) by income

Figure 6.2: Severity of caries patterns in 4-year-old Arizona children by household income.




*Pattern showed significant difference (p<0.05) by income

Figure 6.3: The distribution of caries patterns in 4-year-old Arizona children by household income.



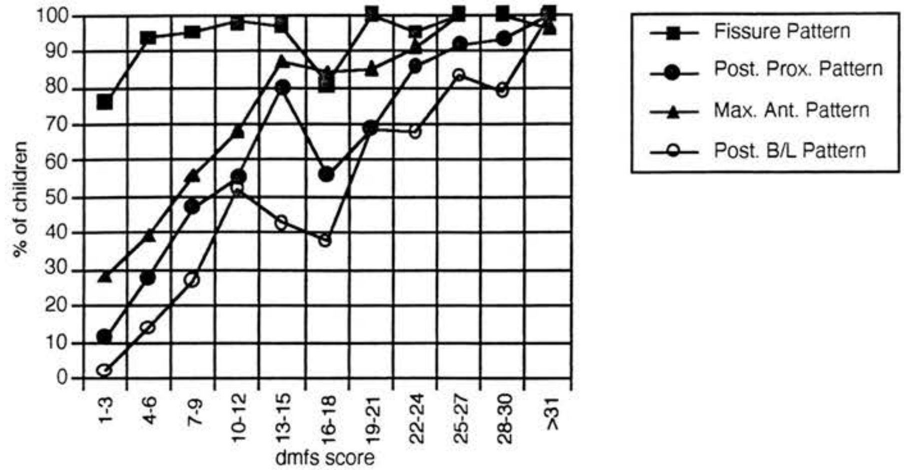

The distribution of the different patterns did not vary by income, however, there was a tendency towards a greater proportion of fissure caries in the high income group. Among the smooth surface patterns there was a tendency towards a greater proportion of posterior proximal caries and a lower proportion of maxillary anterior caries in the high income group compared with the low income group (Figure 6.3).

The relationship between the dmfs index and caries patterns

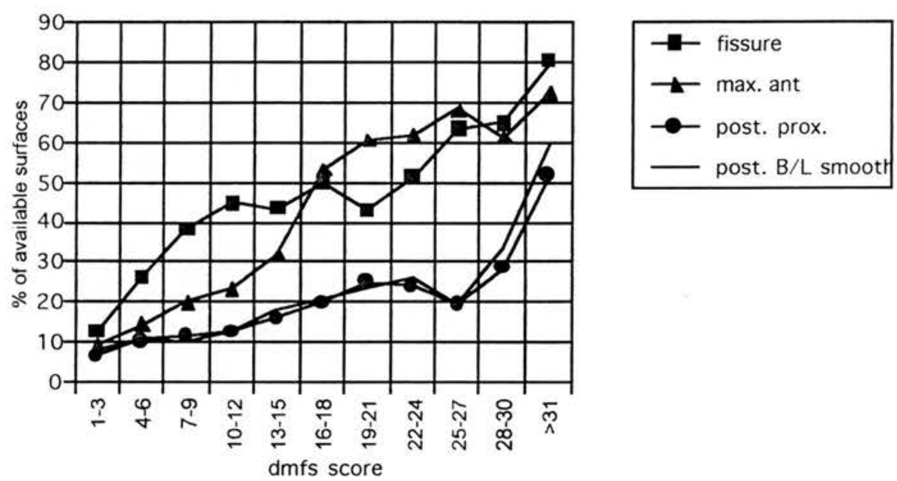
The association of caries pattern prevalence, severity and distribution with dmfs score was examined (Figure 6.4). The prevalence of the fissure pattern approached 100% in all dmfs categories except the lowest. In contrast, the prevalence of the smooth surface patterns was positively associated with the dmfs score. Nearly all children with dmfs scores greater than 25 had maxillary anterior caries and nearly all children with dmfs scores greater than 31 had all the caries patterns. The severity of all the patterns was greater with increasing dmfs score. The posterior proximal and posterior buccal/lingual patterns showed the most rapid increase in the highest dmfs categories. The distribution of the patterns also varied by dmfs score. At the lowest score the majority of the carious surfaces were fissure. With increasing dmfs scores the proportion of fissure caries declined while that of maxillary anterior caries increased. However, in the two highest dmfs categories the distribution of maxillary anterior caries decreased while the distribution of posterior proximal and posterior buccal/lingual patterns increased.

Figure 6.4: Prevalence, severity and distribution of caries patterns by dmfs score in 4-year-old Arizona children.

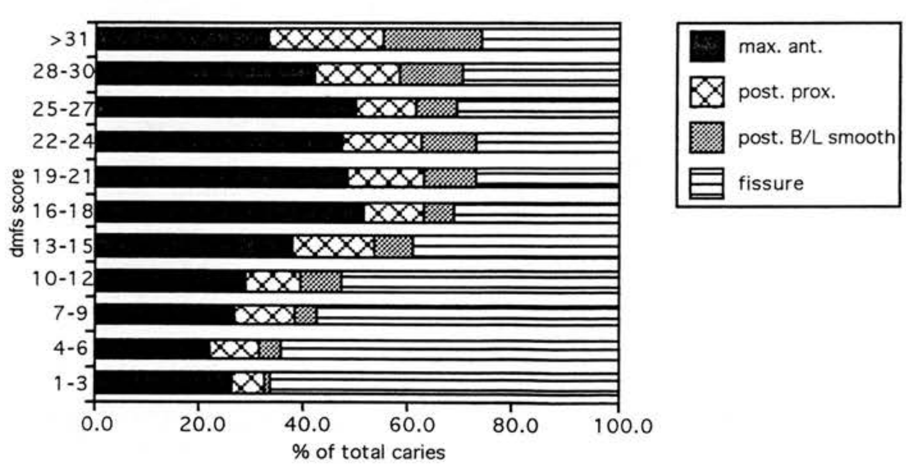
6.4a: Prevalence




6.4b: Severity

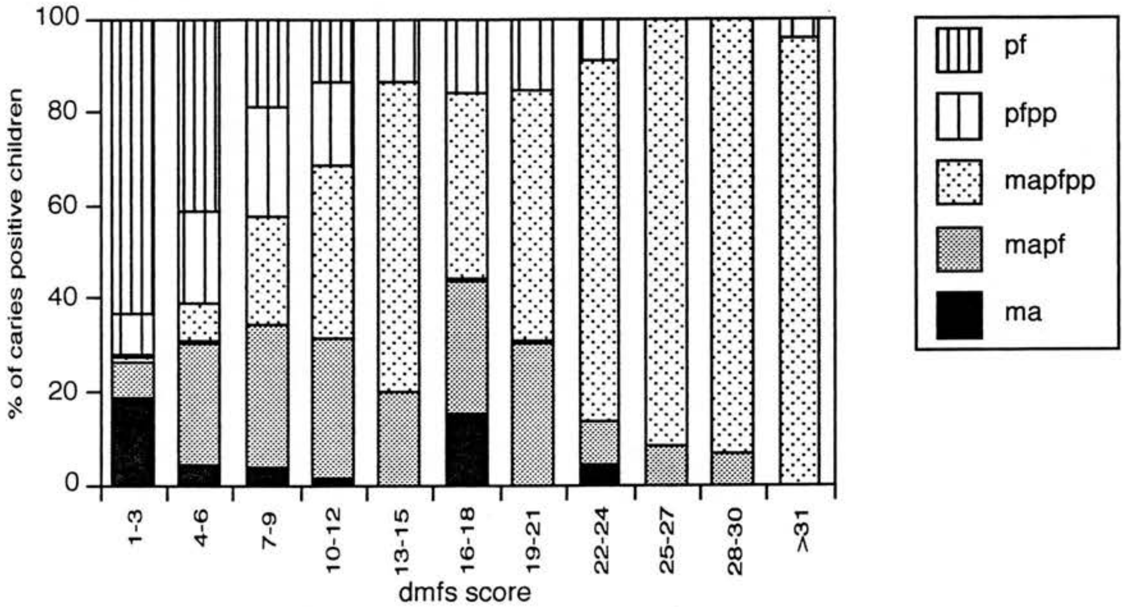



6.4c: Distribution



Pattern combination versus dmfs score was then examined (Figure 6.5). In the lowest dmfs category most children experienced *pf* alone. In the moderate dmfs categories, a greater variety of pattern combinations was seen with a trend towards greater levels of *mapfpp* as the dmfs scores increased. At the highest dmfs scores, *mapfpp*, predominated.

Figure 6.5: The prevalence of pattern combinations by dmfs score among caries positive 4-year-old Arizona children.

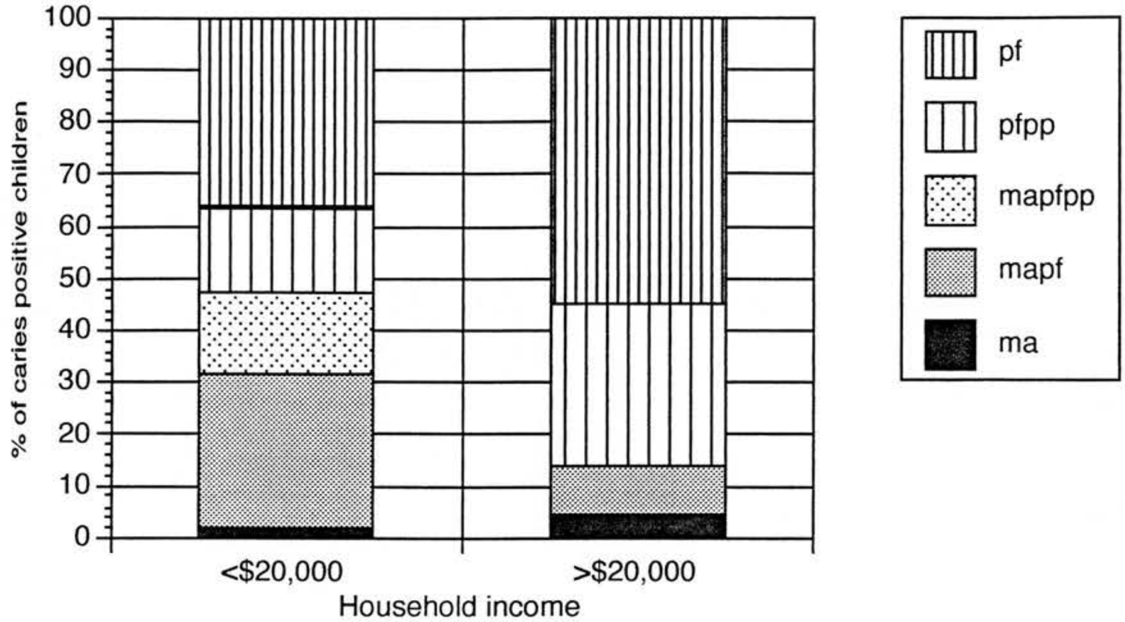



Pattern combinations versus dmfs score to detect differences in caries risk

To determine if caries patterns are a more sensitive indicator of caries risk than the dmfs index it would be ideal to take children with the same dmfs score and determine if the caries pattern combination varied with statistical and clinical relevance by a known risk factor, in this case household income. However, due to insufficient numbers of subjects this was not possible, instead a narrow range of dmfs scores (4-8) was chosen, giving 155 subjects.

Among children with dmfs scores of 4-8 surfaces, no significant difference in dmfs scores was found between those from low (mean dmfs=5.83) and high (mean dmfs=5.50) income households. However, pattern combination did vary significantly between children from low and high income households (Figure 6.6). The high income children experienced almost exclusively the pf and pfpp combinations while nearly 50% of the low income children experienced pattern combinations involving the maxillary anterior pattern (*ma, mapf, mapfpp*).

Figure 6.6: Pattern combination by household income in 4-year-old Arizona children with dmfs scores of 4-8.




The converse test to examine the ability of patterns and dmfs scores to detect differences in caries risk is to select one pattern combination and see if the dmfs score varies by the risk factor. All children with just the *pf* combination (n=200) were selected. No significant difference in dmfs scores were found between children from low (dmfs=3.15) and high (dmfs=2.97) income households.

DISCUSSION

Dental caries appears to be a major health problem for U.S. preschool children (Table 6.1). However, the lack of data from populations other than under-served children hampers understanding of the extent of the problem, the nature of the disease process and the development of appropriate, targeted preventive programs. The population in the present study is more representative than those in other reports but still oversamples children from low-income backgrounds. Fifty-three percent of the four-year-olds whose parents responded to the income question came from households with incomes less than $10,000, while across the United States only 15% of households have incomes of less than $10,000 (Bureau of the Census (US), 1990). However, the data as it pertains to children from lower household incomes may be representative of the United States as a whole as mean dft levels for 5-year-olds in Region V (Arizona, Texas, Colorado and New Mexico) were nearly identical to the national mean in the 1986-87 National Survey of Dental Caries (National Institute of Dental Research (US), 1989).

The caries scores reported in this study for children from low income households are similar to other reports from low income Head Start Hispanic and White children (Table 1). As expected, children from high income households experienced less caries than children in previous Head Start studies (Table 1). Unfortunately, comparison of the present study to the only national U.S. caries examination of preschool children (Kaste et al., 1996) is not possible as the study results were not subdivided by age nor socio-economic status.

The importance of socio-economic status as a caries risk factor in the present study confirms the findings of older studies on preschool children (Wisan et al., 1957; Infante and Russell, 1974 ) and more recent studies on school aged children (Conney et al., 1993; Evans et al., 1993; Slade et al., 1996). Explanations for the association of lower socio-economic status with increased caries include: lower education level; financial restraints that limit the caretaker's ability to care for their children; inability to obtain dental care for children both due to cost and limited access to care; more pessimistic views regarding oral health; children's greater consumption of sugar-containing foods; and poorer oral hygiene (Chen, 1995). It is also possible that socio-economic factors may be correlated with different behaviours. For example, caretakers from lower socio-economic groups may have certain infants feeding practices that affect maxillary anterior caries rates.

The prevalence of smooth surface caries varies by income more than that of fissure caries, suggesting that aetiological factors associated with smooth surface caries were more common in low income children. Such factors may include increased consumption of candy and sugar containing drinks which has been reported in lower socio-ecocnomic groups (Hinds and Gregory, 1995) or infant bottle feeding practices which have been associated with the maxillary anterior pattern. .

In spite of the significant differences in the prevalence of the patterns between the high and low income children, the smooth surface patterns showed no difference in severity between income groups. This finding challenges the theory that the more prevalent the caries the more severe the disease level (Knutson, 1944). Further, these findings suggest that if high income children are exposed to the appropriate cariogenic conditions they do not differ from low income children in their caries susceptibility.

In contrast to smooth surface caries, the severity of fissure caries varies with income. This may be due to the high level of maxillary anterior caries among low income children, a pattern associated with increased severity of fissure caries (Chapter 5). Additionally, earlier development of the fissure pattern compared to the posterior proximal and posterior buccal/lingual patterns may allow more time for lesions to develop and differences in severity to become apparent (Chapter 4).

The different nature of fissure caries versus smooth surface caries is highlighted in the relationship of these patterns with dmfs scores. All children irrespective of dmfs score experience fissure caries, while smooth surface patterns are positively associated with dmfs scores. This suggests smooth surface caries is more often present in children with high caries experience while fissure caries shows little relationship with caries risk. In fact, a previous study found no difference in caries risk factors between children who were caries free and who had fissure caries (Johnsen et al., 1984). This indiscriminate nature of fissure caries also may explain why less difference is seen in the prevalence of this pattern by income status compared with the smooth surface patterns.

The caries risk of children appears to be associated with the combination of caries patterns experienced. Children with high levels of caries are more likely to experience pattern combinations including smooth surfaces caries, especially maxillary anterior caries. This provides further evidence for the role of maxillary anterior caries as a major caries risk factor. Of necessity, children with high caries levels have complex pattern combinations because the fissure pattern alone only can provide twelve carious surfaces. Increased caries scores must come through the involvement of other patterns. However, even at low to moderate dmfs scores, the caries pattern combinations varied by household income, indicating that the surface-specific pattern of caries is of importance when assessing caries risk.

## Conclusions

Mean dmfs scores and caries pattern prevalence vary by household income. While fissure caries is nearly twice as frequent in low income children, maxillary anterior caries is more than three times as frequent. However, the severity of the smooth surface caries patterns does not vary by household income.

The caries risk of children appears to be associated with the caries patterns they experience. Fissure caries is present in all caries positive children whereas smooth surface patterns are more often present in children with high caries experience. These differences explain the ability of pattern combinations to detect differences in caries risk where the dmfs index can not, strongly suggesting that the surface-specific site of caries is more important than the total number of lesions experienced when assessing caries risk.

Caries prevention programs in low income children should focus on the maxillary anterior pattern due to its high prevalence. Maxillary anterior caries develops early and is a risk factor for caries progression onto other teeth, therefore, interventions must be intensive and initiated soon after tooth eruption. Since caries prevalence is lower in high income children, interventions should identify those likely to get caries and preventive approaches should focus primarily on the management of fissure caries.

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# CHAPTER VII

## CONCLUSIONS

There is limited information about the caries experience of preschool children. However, the data available suggests that caries levels have declined since the introduction of the decayed, missing and filled (dmf) index in 1950. Caries is now concentrated in a smaller number of individuals, giving rise to high population variance and non-normal caries distribution. The dmf index in such situations may no longer be adequate to detect differences in caries experience between populations, and may result in low mean values, detracting from the seriousness of caries in affected individuals. In addition, the dmfs index does not distinguish between anatomical differences, specific aetiological factors, and preventive regimes that may affect caries rates in individual teeth and surfaces. These issues collectively suggest that a new method of measuring caries in the primary dentition is required that is better suited to describing caries in populations with lower caries experience, assessing caries risk, examining the role of aetiological factors and evaluating preventive programs.

The proposed method, "The Caries Analysis System" (CAS), was used to describe the caries experience of a variety of populations aged one- to six-years. Four surface-specific caries patterns were identified based on anatomical differences of the tooth surfaces and probable caries aetiology. The percentage of children affected (prevalence), the degree to which these children were affected (severity), and the proportion of total caries each disease pattern represents (distribution) were examined for each caries pattern.

The prevalence, severity, and distribution of surface-specific caries patterns varied with age. The maxillary anterior pattern was the most prevalent pattern and had the greatest distribution in the youngest age groups. Little change was seen in the prevalence and severity among older children although the distribution decreased. The fissure pattern was the most prevalent pattern in the older children with the prevalence and severity generally increasing with age, although less change was seen among the oldest children. The distribution of the fissure pattern did not change with age. Developing later than the fissure and maxillary anterior patterns, the posterior proximal pattern showed the greatest change in prevalence and severity among the older children. The distribution of this pattern steadily increased with age. The posterior buccal/lingual pattern was the least prevalent pattern.

The association of caries pattern experience with age and specific aetiologies suggests that caries patterns may be associated with caries risk. Examination of children with caries showed that the presence of maxillary anterior caries was associated with increased caries risk of the posterior teeth. Socio-economic factors such as household income were also found to be associated with caries risk. All the caries patterns were more prevalent in low income children than high income children, especially the smooth surface patterns, with maxillary anterior caries more than three times as prevalent. However, the severity of the smooth surface patterns did not vary by household income. In fact, caries patterns were found to be more useful than the dmfs index in determining caries risk. The caries pattern experience of children with low to moderate dmfs scores, a group whose caries risk is difficult to determine, was found to vary by caries risk where the dmfs score did not. Children with high caries risk were more likely to have pattern combinations involving maxillary anterior caries.

The findings of the present study provide a foundation for the development of surface-specific caries patterns analysis and suggest that caries patterns may be more useful than the dmf index when analyzing caries experience. However, several limitations need to be recognized. First, most of the populations examined were at high risk for dental caries. Second, few children under the age of three years were included, even though caries may develop as early as 10 months of age. Third, the data collected were cross-sectional and not expressly collected for the development of the CAS. Therefore, determining the origin of multiple surface carious lesions was not possible, likely masking the association of caries patterns with specific aetiologies and risk factors. Fourth, the absence of examiner reproducibility and reliability analysis for some populations combined with variation in caries diagnostic criteria may compromise comparisons both within and between studies. However, the absence of bitewing radiographs which resulted in under-reporting of posterior proximal caries may have had a greater impact on overall caries assessment. Fifth, the posterior buccal/lingual pattern, originally included as a marker of rampant caries, was uncommon. Therefore this pattern could be excluded from future studies without loss of information. Sixth, as with most comparative studies, environmental factors such as fluoride exposure will vary making full comparisons between studies difficult, especially considering the preferential effects fluoride has on the prevention of smooth surface caries. However, as fluoride is now pervasive in processed foods and dentifrices in the United States, it has been suggested that caries variation between fluoridated and non-fluoridated areas may be a smaller issue than when comparing the populations in the classic fluoride studies performed prior to 1980.

To further develop and refine the CAS, future studies should include populations of low and high caries risk with children as young as 10 months. The data should be specifically collected for surface-specific analysis to ascertain the feasibility of determining the origin of lesions. Analysis of examiner reproducibility and reliability should be carried out to ensure a satisfactory standard of caries diagnosis is maintained. Bitewing radiographs should be obtained to enable better description of posterior proximal caries development and its relationship to caries risk and the other patterns. Populations with quantifiable differences in fluoride exposure should be examined to determine the current effect of fluoride exposure on overall caries levels and caries pattern experience. Lastly, data of a longitudinal nature should be analyzed to determine the applicability of the CAS in the longitudinal setting and for the transitional dentition.

Ultimately, caries pattern analysis may be useful in a variety of research and public health settings. Studies investigating caries risk factors may benefit from the use of caries patterns rather than the dmfs index as certain aetiologies, behaviours, and socio-economic factors may be associated with specific caries patterns. For instance, the finding that children from low income families experience a greater proportion of smooth surface caries than children from high income families suggests that different aetiological behaviours or risk factors may result in different patterns of caries. In epidemiological studies the focus of the CAS on those children with disease and its ability to analyze treatment rendered would allow comparisons between populations with differing caries prevalences and/or treatment levels. Additionally, surface-specific epidemiological information could be used to design and monitor prevention programs specific for various caries patterns such as behaviour modification for preventing maxillary anterior caries, sealants for fissure caries, or fluoride and flossing for posterior proximal caries.

Although further research is needed to more fully develop the CAS, it is hoped that it could have a role in the assessment of dental needs and planning of services for community dentistry. Utilization of the CAS can help ascertain whether caries is generalized or concentrated in subsets of the community thus enabling it to be determined if preventive services need to be applied to the whole community or targeted only to high risk children. Secondly, CAS can identify the predominant caries patterns present in the community which, combined with a better understanding of caries etiological and risk factors, could help fine tune prevention programs.